Energy Efficient Scheme based on Low Energy Adaptive Clustering Hierarchical Protocol for Wireless Sensor Network

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Abstract— Energy is the key concern area in Wireless Sensor Networks due to lack of power source, maximum energy is used in transmission of data. This paper proposes a new routing approach based on hierarchical routing protocol LEACH where clusters are refreshed periodically based on remaining energy and distance. We propose that the network area in Q-LEACH protocol on the basis of dividing whole network into four quadrants and each quadrant performs individually. In LEACH-E protocol, all nodes have same energy and same probability of suitable the cluster head. After the first round, energy level of each node changes and then the amount of residual energy of each node is used to select cluster head nodes. The nodes with highest residual energy are chosen on rest of the nodes. In this protocol, cluster head (CH) selection is based on the highest energy by the base station.

Key words: Wireless Sensor Network-(WSN), Low-Energy Adaptive Clustering Hierarchy- (LEACH), Cluster Head (CH), Base Station- (BS), Cluster Members- (CM)

I. INTRODUCTION TO WIRELESS SENSOR NETWORK

A wireless sensor network (WSN) is a group of sensor nodes arranged in a field to monitor physical conditions separately [1]. The architecture of WSN is shown in the figure 1. The hexagon shows the network is made up of many sensor nodes connected to the base station (BS). BS is connected to the internet and through internet. It provides the useful information to the user. There are three core types of units in WSN node, sensing, processing and transmission.

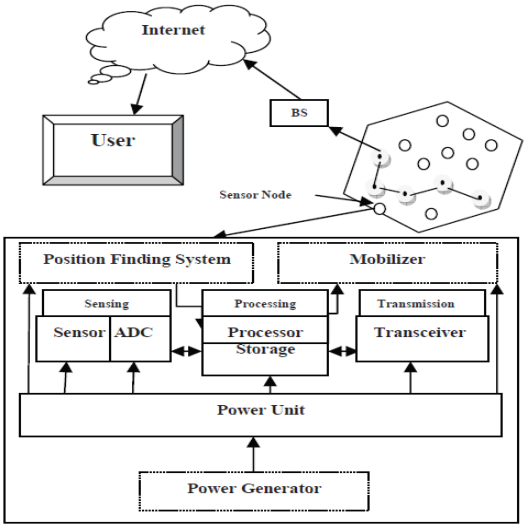

Fig. 1: Architecture of Wireless Sensor Network [2]

Power unit is the necessary part. It generates the power for all the units to work correctly through power generator device. The sensor will sense the particular event as per the application in an analog form. Analog to Digital Converter will convert this sensed analog data into the digital form for more processing. Processor will process converted data and if there is some useful information or parameters, it will use the storage unit. The results are generated and carried forward to the receiver by the transceiver [2].

A. Applications

1) Military Applications:
Monitoring responsive forces, equipment and shells, Investigation of opposing forces and terrain, Front line surveillance, fight damage assessment, Nuclear; biological and chemical attack detection [4], Military situation alertness, and Sensing intruders on basis [5]

2) Environmental Monitoring:
Forest fire detection Traffic control, environment monitoring, Bio-complexity mapping of the environment, Flood detection, Precision agriculture [4]

3) Health Applications:
Tele-monitoring of human physiological data, Tracking and monitoring patients and doctors in a hospital, Drug administration in hospitals [4] Sensors for blood flow, Respiratory rate, ECG (electro cardiogram), Pulse oxymeter, Blood pressure and oxygen measurement [5]

4) Home and Other Commercial Applications:
Home automation and Smart environment, Interactive museums, managing inventory control, Vehicle tracking and detection, Detecting and monitoring car thefts [4]. Location awareness (blue tooth), Person locator [5]

5) Automotive Applications:
The inside and outside conditions of the vehicles, take appropriate actions. Control the vehicle windows' positions in response to rainy, sunny, or snowy weather [4].Active mobility, coordinated vehicle tracking [5]

6) Emergency Situation:
Disaster management, Fire/water detectors, dangerous chemical level and fires [5]

7) Physical World:
Habitual monitoring, Observation of biological and artificial systems, Environmental monitoring of water and soil [5]

8) Industrial:
Factory process control and industrial automation, Monitoring and control of industrial equipment [5]

B. Limitations of WSN

1) Power and Lifetime:
The life of any sensor node in WSN is very important in terms of its working condition. If there isn't power then sensor would leave working. Sensor nodes working on geographically discrete area will use more power.

2) Communication Bandwidth:
There are several sensor nodes in network. So any event will be sensed by more than one sensor nodes to create the unnecessary information transmission. To avoid this information redundancy in order to occupy the data in the small bandwidth, data compression and data aggregation methods are used.

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3) Memory Size:
If the same event will be sensed by more than one sensor then it will create more amounts of data which requires the large storage [2].

C. Advantages and Disadvantages

1) Advantages:
Network setups can be done without fixed infrastructure. Ideal for the non-reachable places such as across the sea, mountains, rural areas or deep forests. Flexible if there is ad hoc situation when extra workstation is necessary. Implementation cost is low-priced [6].

2) Disadvantages:
Less secure as hackers can enter the access point and get all the information. Lower speed compared to a wired network. More complex to configure compared to a wired network. Easily affected by surroundings (walls, microwave, large distances due to signal attenuation) [6].

D. Characteristics of WSN

1) Dynamic Network Topology:
Network topology changes frequently as nodes can be added or removed, node failure, energy depletion, or channel fading.

2) Application Specific:
The network design requirement varies with required application.

3) Energy Constrained:
Nodes are portable and highly limited in energy computation and storage capacities.

4) Self-configurable:
Nodes are randomly arranged without careful planning. Once arranged, nodes have to configure individually themselves into a communication network. [7].

II. ROUTING PROTOCOLS IN WSN

The routing protocols are implemented to optimize energy consumption in the network.

Category	Representative Protocols
Location-based Protocols	MECN, SMECN, GAF, GEAR, Span, TBF, BVGF, GeRaF
Data-centric Protocols	SPIN, Directed Diffusion, Rumor Routing, COUGAR, ACQUIRE, EAD, Information-Directed Routing, Gradient-Based Routing, Energy-aware Routing, Information-Directed Routing, Quorum-Based Information Dissemination, Home Agent Based Information Dissemination
Hierarchical Protocols	LEACH, PEGASIS, HEED, TEEN, APTEEN
Mobility-based Protocols	SEAD, TTDD, Joint Mobility and Routing, Data MULES, Dynamic Proxy Tree-Base Data Dissemination
Multipath-based Protocols	Sensor-Disjoint Multipath, Braided Multipath, N-to-1 Multipath Discovery
Heterogeneity-based Protocols	IDSQ, CADR, CHR
QoS-based protocols	SAR, SPEED, Energy-aware routing

Table 1: Routing Protocols for WSNs Hierarchical Protocols [8]

It defining set of rules to specify how message packets transfer from source to destination in a network powerfully with less amount of energy consumed [7]. All main routing protocols proposed for WSNs divided into seven categories as shown in Table 1 [8].

A sample of layered protocols in a network is collected of several clumps (or clusters) of sensors. Each clump is managed by a special node called cluster head which is responsible for coordinating the data transmission activities of all sensors in its clump [8].As shown in Figure 2, a hierarchical approach divides the network into clustered layers. Nodes are grouped into clusters with a cluster head that has the task of routing from the cluster to the other cluster heads or base stations. Data moves from a lower clustered layer to a higher one. [8].

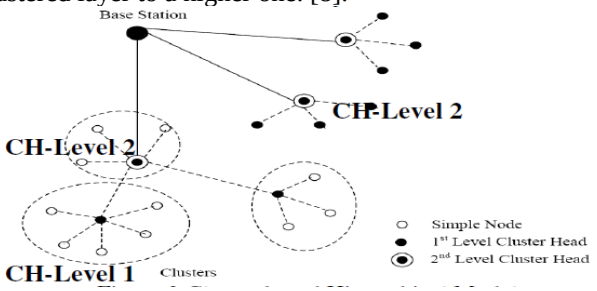

Fig. 2: Cluster-based Hierarchical Model [8]

A. Low-Energy Adaptive Clustering Hierarchy (LEACH):

LEACH is the first and most popular energy-efficient hierarchical clustering algorithm for WSNs proposed for reducing power consumption. The clustering task is rotated between the nodes based on duration. Direct communication is used by each cluster head (CH) to forward the data to the base station (BS). It uses clusters to delay the life of the wireless sensor network [8]. Fig. 3 shows how data is transmitted in LEACH [9].

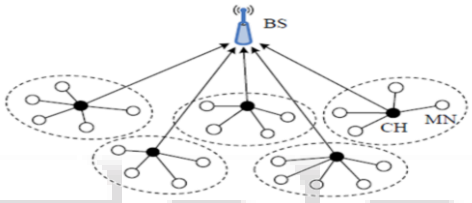

Fig. 3: LEACH [9]

B. Power-Efficient Gathering in Sensor Information Systems (PEGASIS):

PEGASIS is an expansion of the LEACH protocol which types chains from sensor nodes. Each node transmits and receives from a neighbor and only one node is selected from that chain to transmit to the base station (sink). The data is collected and move from node to node combined and lastly sent to the base station. The chain creation is performed in a greedy way. It avoids cluster creation and use only one node in a chain to transmit to the BS (sink) [8].

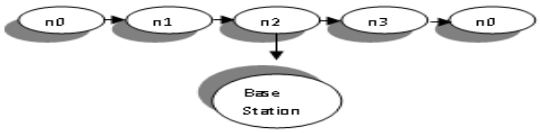

Fig. 4: Chaining in PEGASIS [6]

C. Hybrid Energy-Efficient Distributed Clustering (HEED):

HEED expands the basic idea of LEACH by using remaining energy and node degree or density as a metric for cluster selection to get power balancing. It operates in multi-hop networks using an adaptive transmission power in the inter-clustering communication. HEED was proposed with four primary goals (i) expanding network lifetime by distributing energy consumption, (ii) ending the clustering process within a constant number of iterations, (iii) minimizing control operating cost, and (iv)producing well-distributed CHs and compressed clusters [8].

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D. Threshold Sensitive Energy Efficient Sensor Network Protocol (TEEN):

The TEEN was proposed by Manjeshwar and Agrawal mainly an interesting variation of the important LEACH for a sample of reactive sensor networks. The simple properties of TEEN are: (1) The clustering of nodes and (2) The use of pre-determined threshold value in order to decide whether the data should be transmitted to the base station. [11].

E. Adaptive Periodic Threshold Sensitive Energy Efficient Sensor Network Protocol (APTEEN):

APTEEN is a hybrid clustering-based routing protocol allows the sensor to send their sensed data periodically and react to any unexpected change in the value of the sensed attribute by reporting the corresponding values to their CHs. Figure 5 shows TEEN and APTEEN [6]. APTEEN is an advance to TEEN to overcome its limitations and aims at both capturing periodic data collections (LEACH) and reacting to time-critical events (TEEN) [11].

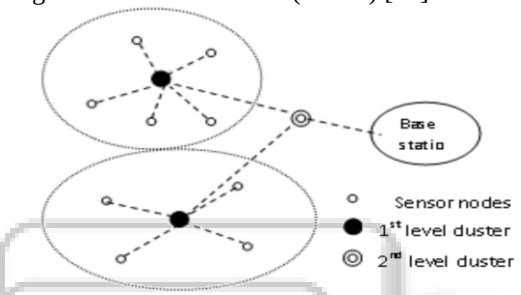

Fig. 5: Hierarchical clustering in TEEN and APTEEN Protocols [6]

F. Energy Efficient Homogenous Clustering Algorithm for Wireless Sensor Networks:

Singh et al. proposed homogeneous clustering algorithm for wireless sensor network that saves power and extends network life. The life span of the network is increased by ensuring a homogeneous distribution of nodes in the clusters. A new cluster head is selected on the base of the remaining energy of existing cluster heads, delay value and nearest hop distance of the node [8].

III. LEACH: LOW-ENERGY ADAPTIVE CLUSTERING HIERARCHY

LEACH is a classic adaptive clustering algorithm proposed by Heinzelman. The algorithm creates the concept of round. Each round is divided into two stages of initialization and constant communication. The initialization phase is divided into selection of cluster head and worry of cluster. The node produces random number between 0 and 1 [13]. LEACH is a self-organizing, adaptive clustering protocol uses randomization to distribute the energy load regularly among the sensors in the network [15].

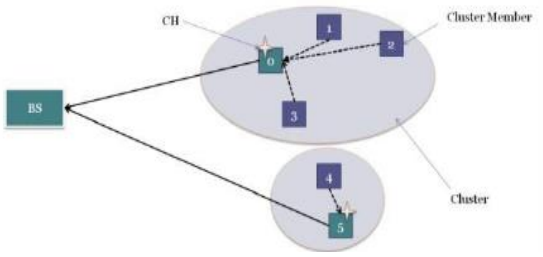

Fig. 6: LEACH basic architecture [16]

Thick network of sensor nodes form clusters and each cluster consists of members called Cluster Members or Normal Nodes and a coordinator node called the Cluster-Head CH. Cluster-heads used more energy than non-cluster heads. Cluster-heads collect the data and forward the message to the BS. The base station is fixed and gone from the sensor nodes as shown in Figure 6 [16].

The communication process is divided into rounds and every round can be split up into two phases, setup phase and steady phase.

A. Setup Phase

1) Advertisement Phase:

Each node decides independently on its own whether it wants to be a CH or not. It uses distributed approach. The decision by every node to be a cluster-head depends upon Percentage of cluster heads out of the total nodes and how many times it has been a cluster head in the previous rounds.

a) Algorithm for the Decision:

The real algorithm is a random number generated by every node ranging in between 0 and 1 and each node compares this number with the threshold value T (n). If that number fall T (n) that node considers itself a CH, the threshold T (n) is set as follows:

$$T(n) = \begin{cases} \frac{p}{1-p*\left(r \bmod \frac{1}{p}\right)} & if\ n \in G \\ 0 & if\ n \notin G \end{cases} \quad (1)$$

Where n is the nodes identification number in the current WSN, r is the current round number, p is the percentage of cluster-heads, G is the set of nodes that have not elected as CH in the last lip rounds. The nodes selected themselves as a CH for the current round use a CSMA MAC protocol and broadcast an advertisement message to the remaining nodes as shown in Figure 7.

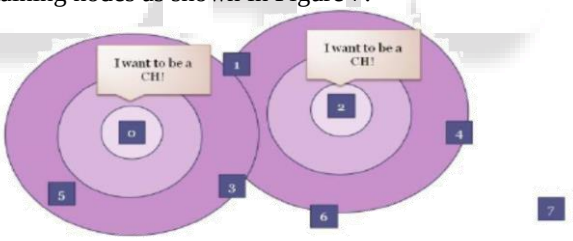

Fig. 7: Advertisement Phase [16]

Normal nodes must stay receivers living to receive advertisements from cluster heads.

- Every sensor node chooses a CH that is at a minimum distance from the node and wants minimum transmission power to decide which cluster to belong to for this round as shown in Figure 8.
- Random cluster-head chosen in the case of ties.
- If a node is outside the range of all Cluster-heads then it sends its data on its own if it has the necessary energy.

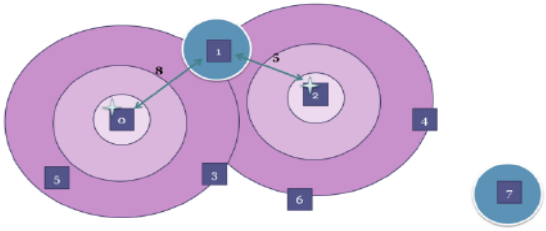

Fig. 8: Choosing Cluster Head [16]

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2) Cluster Set-Up Phase:

After node picks its cluster it tells its cluster-head as shown in Figure 9. Cluster-head now knows its members & their identifiers.

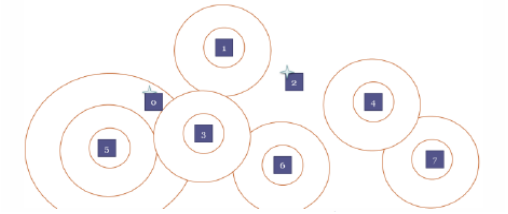

Fig. 9: Setup Phase [16]

B. Steady Phase

1) Schedule Creation

- CH generates a TDMA schedule telling each node when it can communicate its data as shown in Figure 10.
- Node i transmit once per frame.
- Cluster head combined the data received from nodes in the cluster.

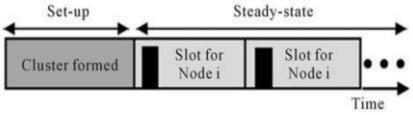

Fig. 10: TDMA Schedule [16]

2) Data Transmission:

Each cluster head forwards its data to the BS. Those nodes are not in the range of any CH forward their data themselves to the BS if they have the necessary energy [16].

IV. VARIANTS OF LEACH PROTOCOLS

A. E-LEACH:

It makes the cluster head selection method capable by making the remaining energy of the cluster head nodes as very important part. It will choose whether these cluster nodes turn into the cluster head or not in the next round. ELEACH will make better election process of cluster head nodes [2].

B. Q-LEACH:

Q-DIR is a restricted flooding routing protocol focuses on a quantified zone using location information supplied by a location service. The location information of the source and destination nodes is associated in the route request (RREQ) packet and publicized. Receiving the RREQ, destination node will send a route reply message (RREP) back to source through the path taken to reach the destination was appended in the RREQ as it crosses across the network.

Figure 11 shows the participating nodes if total flooding is worked that will result in the more routing packets being broadcast in the network.

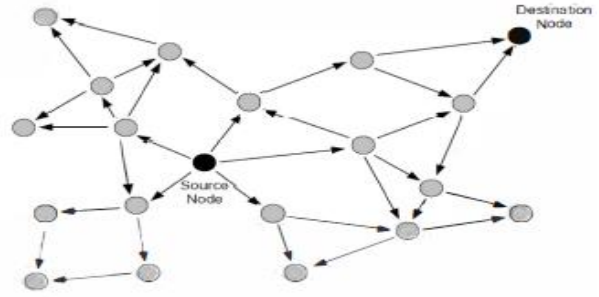

Fig. 11: participating nodes in total flooding algorithm [18]

Figure 12 shows less participating nodes if restricted flooding is worked based on the same quadrant middle is located compared to source and destination.

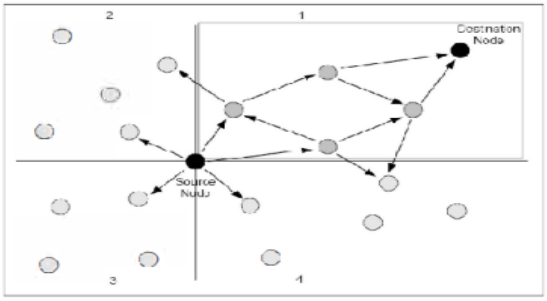

Fig. 12: less participating nodes in q-dir algorithm [18]

Restricted flooding concept is broken in the nodes are located closer to the destination or in a helping zone broadcasts the packet. Distance and forwarding zone information are calculated at the individual nodes to decide their progress towards destination. These nodes will show the packets and the process is repeated at each midway node until it reaches the destination and a uses clustering procedures in which nodes are arranged into cluster and cluster head is distributed to each cluster to execute the data combination and merging to reduce the energy consumed by nodes in the cluster [18].

V. PROPOSED SYSTEM

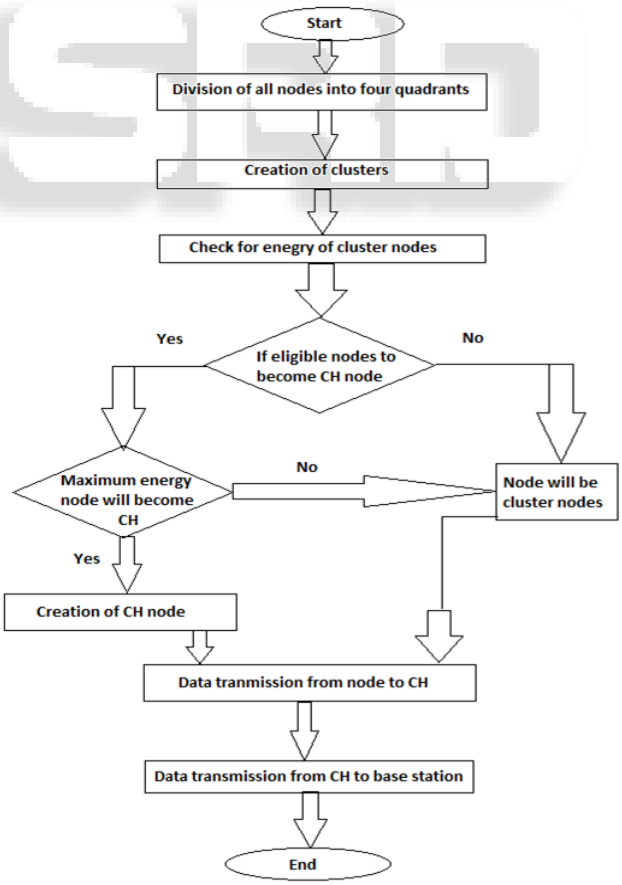

Fig. 13: Proposed System

VI. CONCLUSION

The paper presents an energy efficient clustering algorithm based on LEACH for wireless sensor network. The proposed

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approach will minimize the energy requirements of the sensor nodes. Energy efsficiency is the major parameter in the design of protocols for WSNs as battery power of sensors is limited. In this paper, the functionality of Energy LEACH and Q-LEACH will be combined and in turn, resultant requirement of the energy would be minimized at very extent. Thus, the proposed schema would deliver the combined results of Energy LEACH and Q-LEACH protocols.

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