A Survey - Energy Efficient Routing Protocols in WSN

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Abstract: *Wireless Sensor Network (WSN) contains a group of tiny sensor for monitoring and recording of environment. And the collected data is transferred to the central location or Base Station (BS). Energy is one of the most important resources of sensor node. Energy utilization can be made efficient by selecting proper routing protocols. This paper discuss about some kind of energy efficient routing protocols.*

Keyword: WSN, Sensor node, Routing protocol

1. Introduction

Day by day the role of wireless sensor network (WSN) is increases in the field of science and technology. WSN technology has various applications like health monitoring, environmental monitoring, battlefield monitoring, smart home etc. [2, 3, 4, 5]. Figure 1 shows the WSN composed of two section sensor nodes and Base station (BS). The role of the sensor node is containing the information from the environment. BS gathers the information from sensor node. But the main problem of WSN is energy deficiency. Energy is one of the most important resources of sensor node.
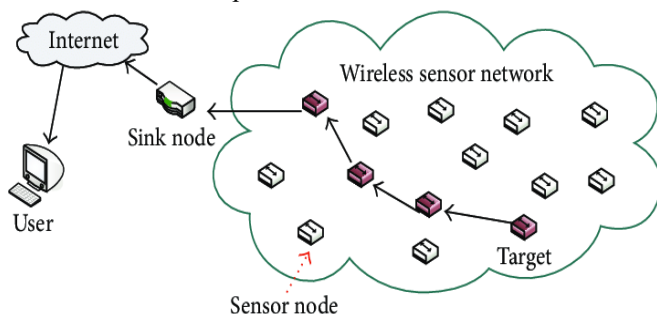

Figure 1: Wireless Sensor Network[1]

Then energy utilization can be made efficient by selecting proper energy efficient routing protocols. Later section contains structure of sensor node, different routing protocols and conclusion.

2. Sensor Node

Sensor nodes are very tiny. But it performs wonderful tasks in almost all the fields [6].Figure 2 shows the structure of sensor node mainly contains 4 units,
1) Sensing unit
2) Processing unit
3) Transceiver unit
4) Power unit

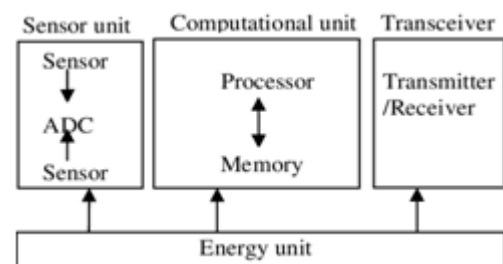**Figure 2:** Structure of Sensor Node

a) Sensing Unit
The sensing unit contain sensor and Analog to Digital Converter (ADC). It gathers data from environment and converts the data from analog to digital signals.

b) Processing Unit
The cerebral part of the sensor node is processing unit, it responsible for processing and storing of collected data.

c) Power Unit
The heart of the sensor mode is power unit. Power unit supplies power to all other unit. If the amount of power is low then it affects all units, after sometimes the entire process will be stopped and the sensor node dies.

d) Transceiver Unit
Transceiver unit is responsible for providing a communication channel from one node to another node in the network.

3. Routing Protocol

Routing protocols [7] is mean to select a suitable path for transmission of data from source to destination. The process encounters several difficulties while selecting the route, which depend upon type of networks, channel characteristics and the performance metrics. A figure 3 show the classification of routing protocols is based on network organization defines how nodes will communicate with each other and how the information will be disseminated through the network.
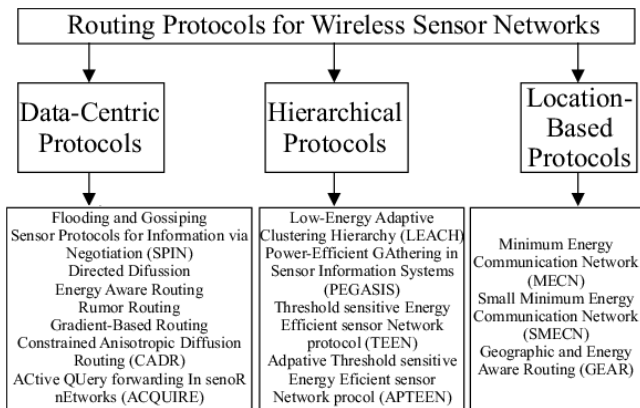
Figure 3: Routing Protocols [7]

4. Data Centric Routing Protocols

This protocol is used to control the data redundancy because the sensor nodes do not have identification number which specifies them uniquely. Then the data is transmitted to each node with significant redundancy. Data centric routing is also a query based protocol because the sink requests for data by sending the query, so that the nearest sensor node transmit the selected data and that is understood from the query. Data centric routing protocol includes: Flooding, Gossiping, SPIN (Sensor Protocols for Information via Negotiation), Directed diffusion, Energy aware routing, Rumor routing, CADR (Constrained Anisotropic Routing), ACQUIRE (Active Query Forwarding in Sensor Network [8].

a) Flooding
It is the forwarding of a packet from one node to other node except the node from which packet arrived. It is distributed routing information to every node in a cage network. The main three disadvantages are implosion, overlapping and resource blindness.

b) Gossiping
The main aim of this protocol is to remove the implosion. This is done by sending information to a randomly selected neighbour. It is also an advanced version of flooding protocol. The main disadvantages of gossiping are very slow process and it takes more times.

c) SPIN (Sensor Protocols for information via Negotiation)
It is a negotiation based protocol in WSN [9]. The main operations of SPIN protocols are in three stages, advertise, request and data. From the figure 4 sensor node A send an advertisement message to all other nodes. Sensor nodes B and C receive advertisement message then it requested to sensor node A for data. Then sensor node A send data to both B and C nodes.
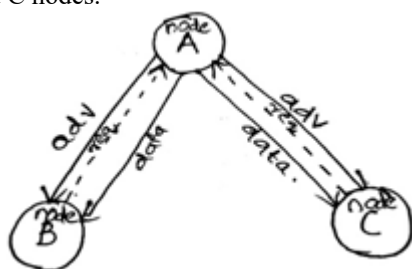

Figure 4: SPIN protocol

The main disadvantage of SPIN protocol is not sure about data will reach the target. It is not good for high density distribution of nodes. And it has more delay.

d) Direct Diffusion
Direct diffusion is the popular data aggregation paradigm for WSN. It is data centric and diffusion based network. It saves energy by the method of diffusion. Direct diffusion contains several elements like interests, data messages, gradient and reinforcement.
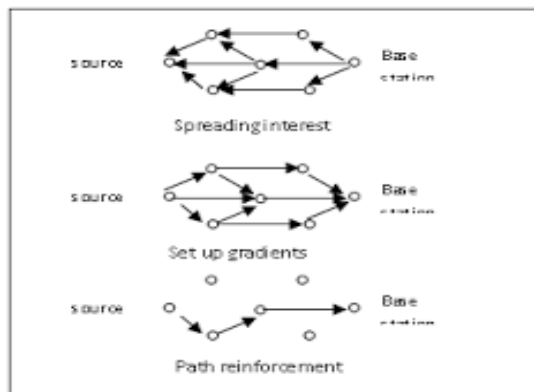

Figure 5: Stages of Direct Diffusion [10]

An interest message is a query. From the figure 5 main function of interest is what a user wants and contains a summary of a sensing task which is supported by a sensor network for acquiring data [10]. Data (collected data) can be event. Event is a short description of the sensed phenomena. Direct diffusion is high energy efficient protocol but it is not a good choice for application because it requires continuous data delivery to the sink that will not work efficiently with a query driven on demand data model.

e) Rumor Routing
The main aim of the rumor routing is to reduce energy consumption by using query or event messages. Basically each node maintains a list of neighbour and an event table. When a node detects an event then generate an agent and this agent travel on a random path.
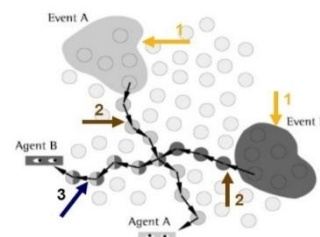

Figure 6: Rumor routing Protocol [11]

Two events A and B are perceived on some nodes. Event is presented then agent is formed. From figure 6, Event A contains an agent A and Event B contain an agent B. At an instance Agent A and Agent B meets. It goes onto spread information about both Event A and Event B.Rumor routing contains some drawbacks. It is applicable the number of events are small and cost of maintaining a large number of agents and large event tables will be prohibitive. Only one is possible in between source to sink

f) CADR (Constrained Anisotropic Diffusion Routing)

It is general form of directed diffusion and in this two type of nodes are present, Line powered Sensors (no energy constraint) and Battery powered sensors (limited life time). In this CADR diffuses queries by using a set of information criteria to select which sensor can get the data. CADR is more energy efficient than direct diffusion because queries are diffused in an isotropic fashion [12].

g) ACQUIRE (Active Query Forwarding in Sensor Networks)

In this BS node sends, the receiver not receive the query and responds to it. According to the information contain in it [12]. Any nodes receive the query then that node responds to the received query by using its information. Then forward it to another sensor node. After this query contain information about that node. Once the query is being resolved completely, query sends all information in to BS through the selected shortest path.

5. Location Based Routing Protocols

In this type of routing protocols [13] the sensor node knows about their locations. And the distance between two nodes are calculate on the basis of incoming signal strength. By exchanging information between neighbours or by communicating with satellite using GPS that leads to obtained relative coordinates of neighbour nodes. The main advantage of this protocol is conversation of energy, to save the energy by demand of the node. If some nodes are high and low demand, the high demand nodes are activate the process and low demand nodes should go to sleep. The main examples of this protocol are GAF and GEAR.

a) GAF (Geographic Adaptive Fidelity)

It is an energy aware routing protocol [14]. It is for MANETs but it is also for WSN, because it conserves energy more by at idle time the transmission and reception of packets are occurs. The main process in GAF is turning off a unnecessary sensors while keeping a constant level of routing fidelity. The figure 7 shows that the three stages of GAF routing protocol. 1. Discovery state. 2. Active state. 3. Sleeping state.
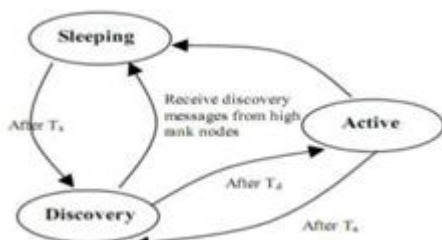

Figure 7: GAF Routing Protocol [14]

A sensor node contains discovery message that uses the message to learn about other sensor in the same grid. And in the active state sensor node broadcasts its discovery message to all other sensor nodes. Which node information is equivalent to the discovery message of initial sensor node then initial sensor node and received sensors are same state.

To maximize the network time by maintain residual energy and ranking of sensor node. Ranking is length of lifetime. Initial sensor node and received sensor nodes are contain only one active state depend upon their ranking. And the ranking is also depends their residual energy. A sensor in the active state has a longer lifetime than a sensor in the discovery state.

b) GEAR (Geographic and Energy Aware Routing)

It is also an energy efficient routing protocol. Its operation is based upon the routing queries to target region in the sensor field. In the sensor contain a localization hardware equipped with GPS unit or localization system. The sensors are depends its residual energy and neighbours residual energy. It uses energy aware mechanism that is based upon the geographical information about the selected sensor to forward a packet towards its destination region. Mainly two types of algorithms are present [15]:

- *Forwarding packets towards the target region*: A node receives a packet, and then it checks its neighbour which is closer to the target region than itself. If the neighbours are more than one, then select the nearest neighbour to the target region. And that sensor node becomes a next hop.
- *Dissemination of packet within target region:*In this phase main mechanism is recursive geographic forwarding. That means once packet reaches target region flooding is occurs that leads to more energy expensive since each nodes needs to broadcast and all of its neighbour need to listen. Packets are sent to small sub region.
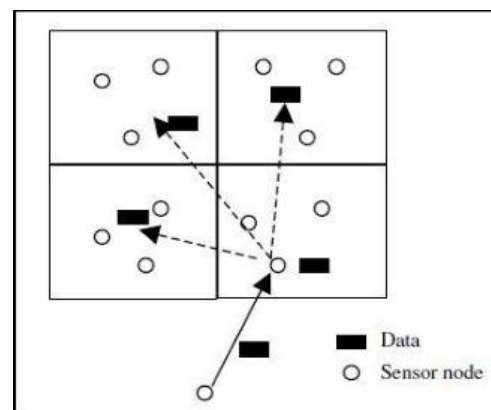

Figure 8: GEAR Routing Protocol [15]

6. Hierarchical Based Routing Protocols

Hierarchical based routing protocol is better routing protocol is better routing compared to above two. The sensor nodes are divided into clusters and the chain based protocol. Each cluster contains some sensor nodes and one cluster head. This cluster head control and collect the data from the other nodes. In the chain based protocols contains one leader node, that leader nodes control and collect the whole data of every nodes in the sensor field. The main aim of hierarchical based routing protocol is to increase lifetime and efficiently maintain the energy consumption of sensor node Example;

LEACH, PEGASIS TEEN, APTEEN and CLP Protocols [16].

a) LEACH (Low Energy Adaptive Clustering Hierarchy)
It is a cluster based routing protocol. A number of sensor nodes are present. All nodes cannot directly communicate with BS because of the occurrence of overlapping, collision and implosions that may leads to reduce the energy and network lifetime. From figure 9 the sensor nodes are divided into some clusters. Each cluster contains a four or five sensor nodes and one cluster head.
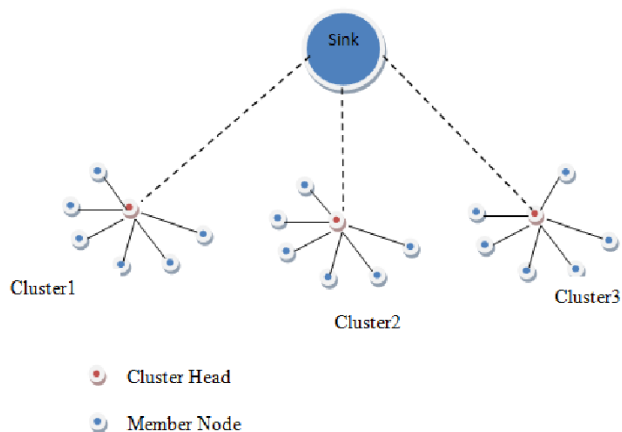

Figure 9: LEACH protocol [17]

The main duty of cluster head is collect the information and data from other nodes, the collected data is transfer to the BS. Figure 11 show the phases of LEACH protocol.

1. Setup Phase

The main processes occurs in this phase is cluster head selection and cluster formations. Each sensor nodes are volunteers itself to become a cluster head. The cluster node selection on the basis of random number lies between 0 and 1. And also the cluster heads are chosen on the basis of its threshold value. If the selected random number is less than the calculated threshold T (n) that sensor node becomes a cluster head.

$$T (n) = P/ (1-P[r \bmod (1/P)]) \quad \text{if } n \in G$$
$$0 \qquad \text{Otherwise}$$

Where,

P, cluster head probability
r, current round
G set of nodes that have not been cluster heads in the 1/p rounds

After the selection of cluster head, head node broadcast an advertisement message to all other nodes. This advertisement message contains node ID and header. Nodes receive this advertisement then nodes receive then it sends a join-Request message back to the cluster head node. The cluster head allocates TDMA schedule to avoid collision among the non-cluster head nodes for data transmission.
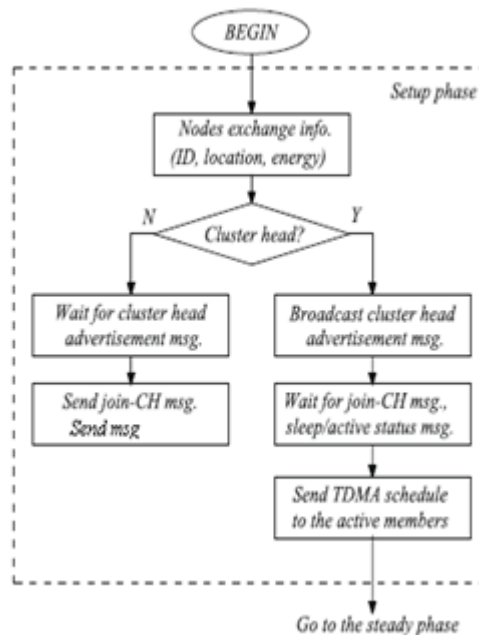

Figure 10: Flow chart of the Setup Phase [18]

2. Steady Phase
Main step of the LEACH protocol is data transmission this can be occurs in the steady phase. This phase contain mainly three parts based on the functionality performance.

- *Data transmission to cluster head*: The member nodes start sending their respective data to the cluster head node during their allotted TDMA slot
- *Data fusion:* cluster head node aggregate the collected data
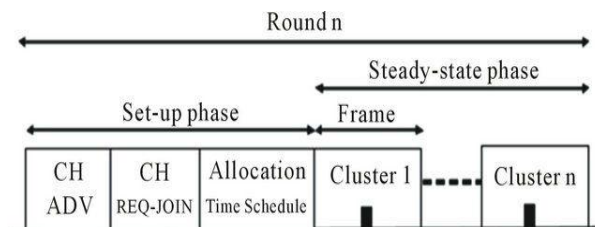- *Data transmission to BS :* The fused data is transmitted to the BS

Figure 11: Phases of LEACH protocol [19]

LEACH is energy efficient protocol but it has some disadvantages. The selection of a node is done based on the usage of energy and threshold conditions, not amount of energy. Uneven distribution, of clusters indirectly creates an unbalanced energy loads on the cluster head nodes. It cannot be used for larger networks and Extra overhead is required for repeated cluster formation, cluster head selection, advertisement messages, etc. [20].

A. TEEN (Threshold Sensitive Energy Efficient Sensor Network)

It is also a cluster based hierarchical routing protocol. It is an improved version of LEACH protocol [21]. In this protocol mainly two assumptions are.

1) BS and sensor nodes have same initial energy

2) The BS can transmit data to all nodes in the network directly.

From figure 12 the network consist of some simple nodes, first level and second level cluster heads. First level cluster heads are formed far away from the BS and second level cluster heads are formed near to BS. TEEN contains mainly two type of threshold are present, Hard threshold (HT) and Soft threshold (ST). HT means the nodes transmit data if the sensed attribute is in the range of interest and thus it reduces the number of transmission. In the case of ST any small change in the value of the sensed attribute is transmitted. The nodes sense the medium continuously and store the sensed value for transmission. The nodes transmits the sensed value through following conditions are satisfied.

- The Sensed value greater than HT
- The Sensed value HT greater than or equal to ST

The main disadvantage of TEEN protocol is, if the threshold are not defined then the communication between nodes are not possible. The user will not get any information from the network. Thus this network is not applicable for regular basis data collection.
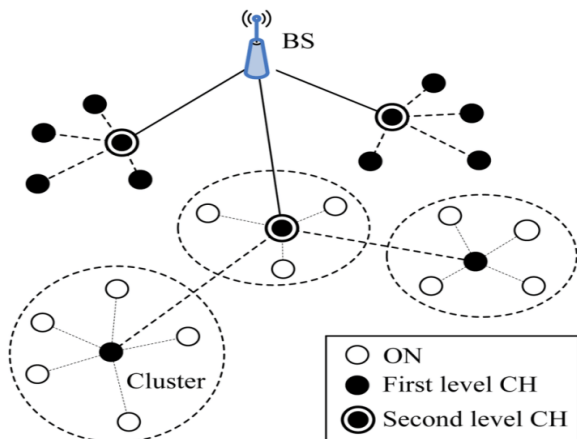

Figure 12: TEEN and APTEEN Protocols [22]

B. APTEEN (Adaptive Threshold Sensitive Energy Efficient Sensor Network)
It is improved version of TEEN protocol [22]. The structure of APTEEN protocol is similar to the TEEN protocol. In each cluster period once the cluster head decided and the cluster head broadcasts by some parameters like Attributes (set of physical parameters, which user is interested to obtain data about), Thresholds (HT and ST), Schedule (TDMA schedule) and Count time (Tc , it is maximum time period between two successive data sent by node. And it is multiples of TDMA schedule length).

C. PEGASIS (Power Efficient Gathering in sensor Information System)
It is a chain based approach protocol. It is also improved version of the above protocols. In this so many sensor nodes are present and one node become a leader node. Figure 13 shows the leader node collects the fused data from the sensor nodes to the BS. Each node communicates only with a close neighbour and take turns to transmit the data to the BS. It performs better than LEACH, TEEN and APTEEN protocols. The performance of the pegasis contains three steps:

1) Leader Node Selection
First assume that the BS has a high range of transmission capability [23]. BS will send a broadcast message to all nodes. Each sensor node measures the broadcast signal strength from the BS using RSSI (Received Signal strength Indication). If this RSSI [25] value is greater than predetermined threshold T (n), then that node become a leader node.

2) Chain Formation
The chain construction is start from the furthest node from the BS. Greedy approach is used to construct the chain. Each sensor node communicates or transmits its data to the neighbouring nodes. At last the leader node contains the information of all nodes.

3) Gathering Data
After the selection of leader node and chain formation, the fused data in the leader node is sends to the BS. When a node dies, chain is reconstructed to bypass the dead node.

PEGASIS protocols contain some disadvantages like when a head node is selected; there is no consideration how far the BS is located from the head node and its energy level is not considered .There is only one node head; it may be the bottle neck of the network causing delay. Redundant transmission of data as only one head node is selected.
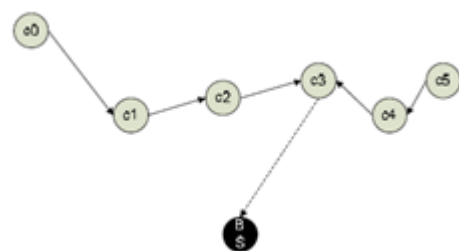

Figure 13: PEGASIS Protocol [23]

D. Combined LEACH and PEGASIS protocol
The designing of this protocol is shown in the figure 14. It takes advantages of the LEACH and PEGASIS protocol. The main advantage of LEACH protocol is formations of cluster and PEGASIS protocol is construction of chain.
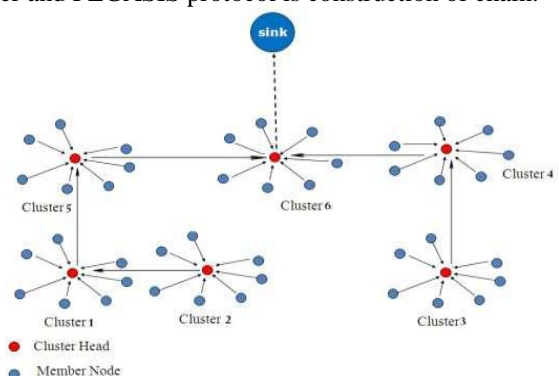

Figure 14: Structure of Combined LEACH and PEGASIS protocol [24]

LEACH protocol is used to selection of cluster head in the WSN network. PEGASIS protocol is used to construct a chain between all cluster formed by LEACH protocol. From figure 15 at last one node is responsible to send the data to the BS.
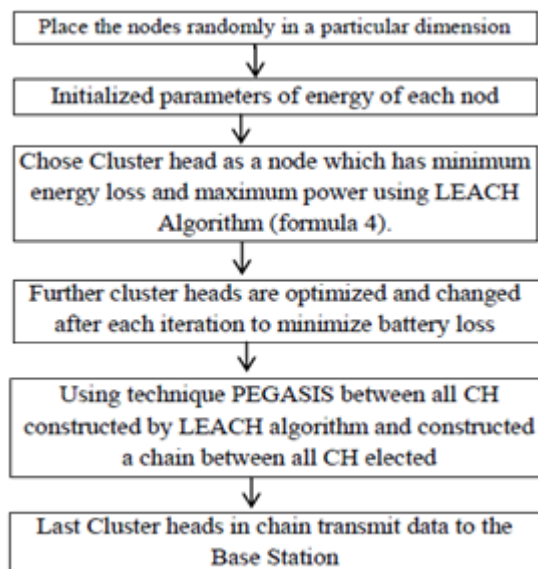
Figure 15: Flowchart of CLP protocol [24]

7. Conclusion

The role of WSN increases in the field of communication. Routing protocols are containing main part of the WSN. By using the routing protocol the communication will be very fast, conserve more energy and also increase the network lifetime. Different kinds of routing protocols are present. But each protocol contains some disadvantages like implosion, overlapping, collision, time delay, redundant transmission etc. The latest version of routing protocol is combined LEACH and PEGASIS protocol. This protocol contains also some disadvantages. Minimizes this disadvantages and to develop or discover a new kind of protocol.

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