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Review Article

Cluster Based Energy Efficient Routing Protocols for Wireless Sensor Networks

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Abstract: In recent times wireless sensor networks have grown extremely and become increasingly striking in big variety of applications due to their low cost, low power, small in size, self-organizing behavior in unsympathetic environments. Routing is a vital technology in WSN. There are many routing protocols like: Location-based Protocols, Data Centric Protocols, Hierarchical Protocols, Mobility-based Protocols, Multipath-based Protocols, Heterogeneity-based Protocols, quality of service (QoS)-based Protocols etc. Clustering is used to protract the lifetime of the wireless sensor networks. It involves grouping of sensor nodes into clusters and electing cluster heads (CHs) for all the clusters. CHs collect the info from respective cluster's nodes and forward the aggregated data to base station. In this paper we present the study of various clustering-based energy efficient routing protocols of wireless sensor networks and compared them on various parameters. like Delivery Delay, Algorithm Complexity, Energy Efficiency, Load Balancing.

Keywords: Routing Protocols, Energy Efficient, Network lifetime and Base Station (BS).

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INTRODUCTION

In these days, wireless sensor network emerging as a capable and interesting area. Homogeneous and Heterogeneous nodes are used in wireless sensor network where a wireless medium is used by the nodes to communicate with each other. A hundred to thousands of nodes can be deployed in the sensing expanse to sense the environment. These nodes work considerately and send sensed information to the sink (Master Node). Wireless sensor network can be divided into two types: **(i) Unstructured WSN**- is one that contains a dense collection of sensor nodes. Sensor nodes may be randomly deployed into the field. Once deployed, the network is left unattended Page 2 to perform monitoring and reporting functions. **(ii) Structured WSN** – In a **structured WSN**, all or some of the sensor nodes are deployed in a pre-planned manner. The advantage of a **structured** network is that fewer nodes can be deployed with lower network maintenance So, the maintenance of structured WSN is much easy as compare to Unstructured WSN [1]. Sensor nodes work considerately to monitor environment conditions such as temperature, sound, vehicular movement, pressure and pollutants. The sensor nodes are deploying in the sensing area through wireless links which provide opportunities for many civilian and military applications, for example: intrusion detection, battlefield monitoring and availability of equipments, environment observation and home intelligence. Basically, a sensor node is made by four components: a sensing unit, a processing unit, a communication unit, a power unit. A sensing unit is made up of one or many sensors and analog to digital convertor. Where the sensor nodes sense the physical occurrence and generate the analog signal. Then the ADC convert these analog signals in digital signals which are sensed by the sensors. After the conversion of the signals, they are fed into processing unit. The processing unit has limited memory (storage) and processor (microprocessor) provides full control to sensor nodes. A communication unit use radio for data transmission between nodes. The most important component or unit of a sensor node is power unit which supply power to the nodes. There can be more components or units can be added to the sensor node, depending on different applications.

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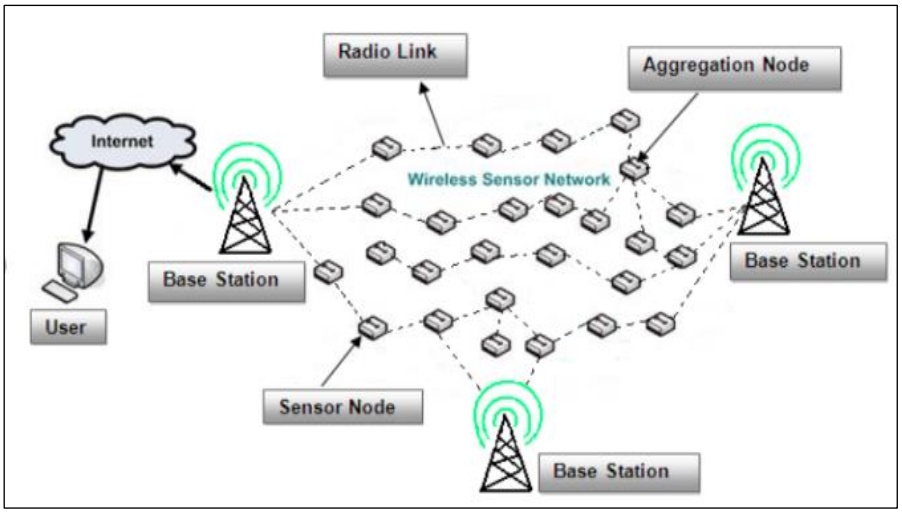

Fig 1.1: Basic Architecture of Wireless Sensor Network

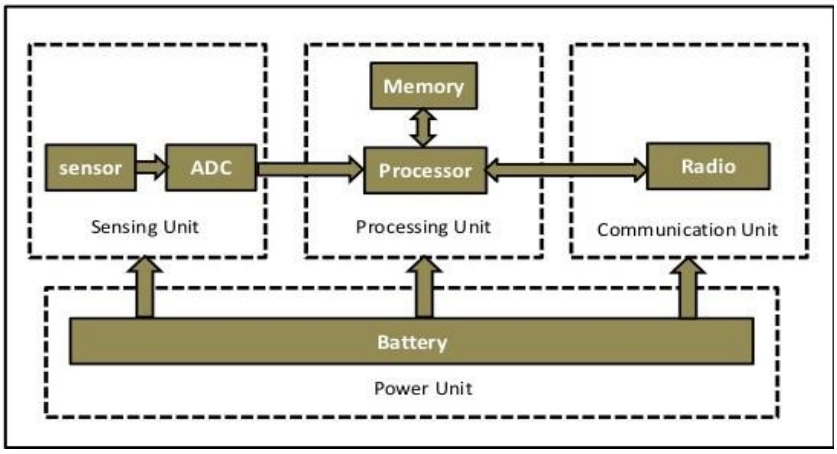

Fig 1.2: Components of sensor node

Wireless Sensor Network Protocol

The protocol stack used by the sink and the sensor nodes is given in Fig. 3. This protocol stack combines power and routing attentiveness, integrate data with networking protocols, communicates power proficiently through the wireless medium and promotes accommodating efforts of sensor nodes. The protocol stack consists of the application layer, transport layer, network layer, data link layer, physical layer, power management plane, mobility management plane, and task management plane. Different types of application software can be built and used on the application layer depending on the sensing tasks. This layer makes hardware and software of the lowest layer transparent to the end-user.

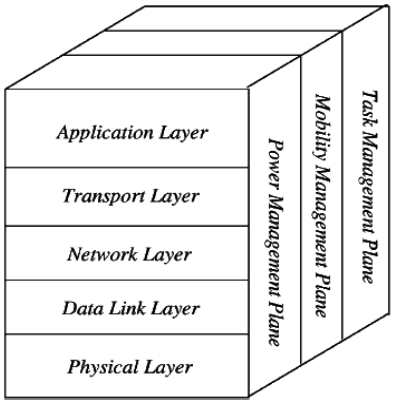

Fig 2.1: Wireless Sensor Network Protocol Stack

The Sensor Nodes: These planes help the sensor nodes coordinate the transport layer helps to maintain the flow of data if the sensor networks application requires it. The network layer takes care of routing the data supplied by the transport layer, specific multi-hop wireless routing protocols between sensor nodes and sink. The data link layer is accountable for multiplexing of data streams, frame detection, Media Access Control (MAC) and error control. Since the environment is deafening and sensor nodes can be mobile, the MAC protocol must be power aware and able to minimize collision with neighbors' broadcast. The physical layer addresses the needs of a simple but robust modulation, frequency selection, data encryption, transmission and receiving techniques. In addition, the power, mobility, and task management planes monitor the power, movement, and task distribution among the sensing task and lower the overall energy consumption.

Clustering In Wireless Sensor Networks

Traditional routing protocols for WSN are not enough most favorable in terms of energy efficiency and load balancing. Clustering is introduced to balance the load and increase the lifetime of the network. Clustering is sample of layered protocols where the network is self-possessed of several clusters of sensor nodes. As shown in fig.4, each cluster has a leader node which is also called as cluster head. CH takes data from all the nodes in its cluster. Cluster head comprehensive all the data received from cluster members and then send that data to the base station. The transmission between cluster members and cluster head is said to be intra cluster communication, whereas the conduction between cluster head and sink is known as inter cluster communication. The local collaboration in clusters, reduce the bandwidth demands. Clustering reduces the routing overhead and make the network more stable [2].

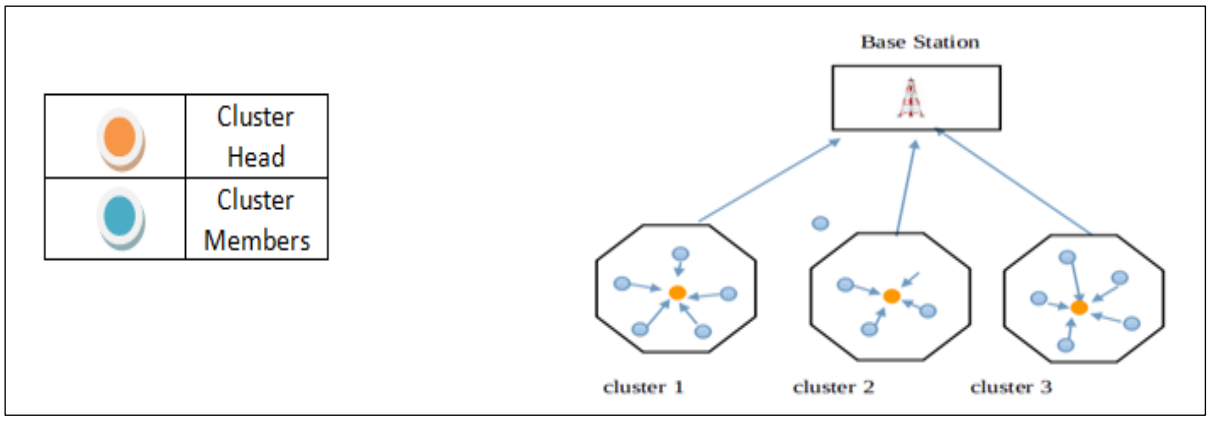

Fig 3.1: Clustering in WSNs

Characteristics of in Clusters

1. Every node should be in one cluster [3].
2. Guarantee the total coverage of network.
3. Number of cluster head should be less so that there will be less overlapping of clusters and which will improve energy efficiency.
4. Clustering should be uniform and balanced.

Energy-Efficient Clustering Protocols

Sending data from source node to destination node is called routing. In routing process intermediate nodes can also collaboratively participate. The routing can be done hop by hop or end to end. In hop by hop routing the intermediate nodes are used to route the data.

LEACH

Low energy adaptive clustering hierarchical is a clustering based protocol. In which the network is divided into clusters. Each cluster has some number of nodes where each cluster has a cluster head. CH is chosen from the nodes in the network based on their receiving signal strength. After each round the cluster head is changes which collects the data from other nodes in the cluster and send the data to the sink. 5 percentage of total number of nodes are chosen as cluster head. Various modifications have been made to the LEACH protocol such as TL-LEACH, E-LEACH, M-LEACH, LEACH-C, V-LEACH, LEACH-FL, W-LEACH, T-LEACH

IBLEACH

It is improved version of LEACH. Some high energy nodes declare themselves to be gateway nodes and send ADV (advertisement) messages to other non-gateway nodes. The other non-gateway nodes with maximum energy declare themselves to be cluster head and send ADV messages to non-cluster nodes. The non-cluster nodes can receive two or more ADV requests. A node sends Join-Request to that cluster head which require minimum communication energy. Each node starts their task after the construction of clusters [4].

PEGASIS

(Power-efficient gathering in sensor information system) A chain of sensor nodes is made instead of clusters. All the nodes in the chain can transmit and receive data from its neighbor nodes. The node that starts transmitting data is called as an end node. Then the other nodes in the chain starts receiving data and send the data to its next neighbor after aggregating data. This process continues till the last node in the chain which is

elected as leader node Leader node sends data to the sink. Multi-hop routing is done in PEGASIS. There is delay for the nodes which are far away from the leader node in the chain. The bottleneck problem occurs at the leader node. When numbers of transmissions among the non-leader nodes are less than that leads to overall energy efficiency [5].

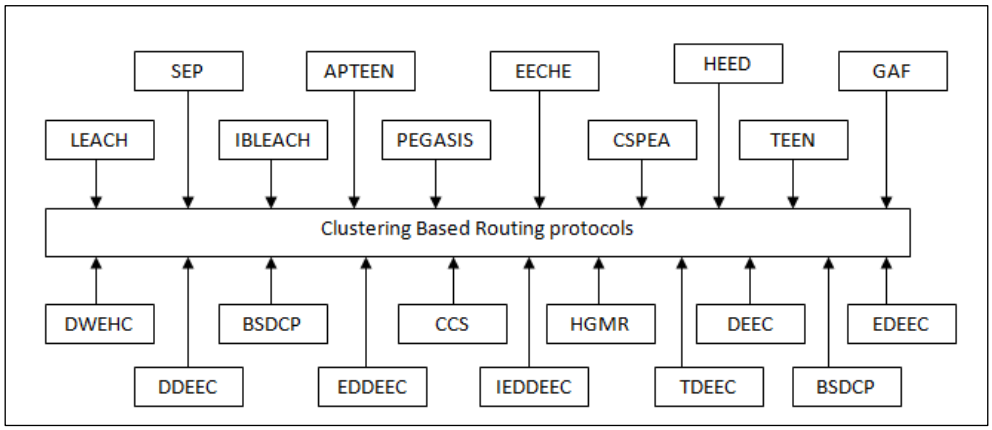

Fig 4.1 Clustering Based Energy Efficient Routing Protocols

CSPEA

(Constrained shortest path energy aware routing) Network is divided into clusters where each cluster has a cluster head and a gateway node is used to connect them. Estimation of energy consumption can be made by calculating distance from source to destination. Energy efficiency can be achieved by choosing best path for data routing. It is the best approach because it entails less control packet overhead. In data cycles, the nodes send data to gateway nodes. In routing cycle, the routing state of all sensor nodes is maintained by its cluster head. The transmission power to send data from one node to another node is calculated by distance between sender and receiver nodes. A constraint can be added in this technique i.e. rerouting. This is carried only when; 1. Sensor nodes reorganized in the cluster, 2. Battery level of sensor nodes decreases.

TEEN

(Threshold-sensitive energy-efficient sensor network protocol) TEEN protocol is used for precipitous changes in the sensed attributes in the network. It uses a data centric mechanism and makes clusters in a hierarchical fashion. Two threshold values are broadcast to the nodes: hard threshold and soft threshold etc. The hard threshold is the minimum possible value of an attribute. Sensor nodes send data to the cluster head only if they found the sensed value is greater than the hard threshold.

SEP

(Stable election protocol) It is improved version of LEACH. It operates like LEACH but the difference in SEP that there are two types of nodes; 1. Normal nodes, 2. Advance nodes which has different level of energy. In SEP, weighted election probabilities are used to select the cluster head from all the sensor nodes according to their energy [6].

APTEEN

(Adaptive TEEN) This protocol is used to capture the data periodically. Three types of data query are made: historical, one time, persistent etc. In historical, the previous recorded values are analyzed and further decisions are also being taken based on their value (previous value). In one time, the snapshot of current network is taken and also envisioned (visualized). In persistent, when a event takes place than it monitors the network [7].

EECHE

Energy-efficient cluster head election protocol is the improved version of Prim's algorithm. Some sensor nodes use additional energy resources. The cluster head broadcast the TDMA schedule to all sensor nodes and based on that TDMA schedule the sensor nodes participate in the network operations. Otherwise they will turn off their radio when they are not participating. This process minimizes the energy consumption. This protocol reduces energy consumption of those nodes which are far away from the sink and balance the energy consumption which are near to the sink. Routing is done based on the residual energy of the cluster heads.

HEED

Hybrid Energy-Efficient Distributed clustering is different from LEACH in the manner of CH election; HEED does not select nodes as CHs randomly. Cluster formation is performed based on the hybrid combination of two parameters. One parameter depends on the node's residual energy and the other parameter is the intra-cluster communication cost. In HEED, elected CHs have

relatively high average residual energy compared to member nodes.

GAF

Geographic adaptive fidelity locates nodes in the network and makes the best use of them to have a better fidelity. All the nodes use a location identification technique to locate itself with its nearest neighbors by using location-information systems like GPS. In GAF, all the nodes arrange themselves according to grids also. All the nodes divide themselves in grids and all nodes which are under a same grid coordinate among themselves to see who will go into sleep state and for how long. Nodes in grid A can communicate with all the nodes in grid B that are adjacent. The time for sleeping is decided or depends on the application. GAF has three state states, discovery, active and sleeping. Every node starts with the discovery state. In this state the node turns on its radio and starts sending discovery messages. A node can fall into sleep state if there are other nodes in the grid which are equivalent in handling the fidelity before falling into the active state. In the active state the node sets a timeout value Ta which shows the remaining amount of time for which a node is intended to stay in active state. A node enters into sleeping state either from the discovery state or from the active state where Td is discovery time, Ta is active time and Ts is sleep time [8].

HGMR

Hierarchical Geographic Multicast Routing is location-based multicast protocol. This protocol incorporates the key design concepts of the Geographic Multicast Routing (GMR) and Hierarchical Rendezvous Point Multicast (HRPM) protocols. HGMR decompose the multicast group into subgroup. HGMR apply the local multicast scheme of GMR to forward data packets along multiple branches of the multicast tree in one transmission. In HGMR, the multicast group is divided into subgroups using the mobile geographic hashing: the deployment area is partitioned into a number of equal-sized square sub-domains called cells and each cell comprises a manageably-sized subgroup of members. In each cell there is an Access Point (AP) responsible for all members in that cell, and all APs are managed by a Rendezvous Point (RP) [9].

DEEC

Distributed energy-efficient clustering is also based on LEACH protocol and used for heterogeneous WSN. The network is divided into clusters and each cluster head is chosen by a probability of ratio between residual energy of each node and average energy of the network. DEEC is better than LEACH, SEP because it has longer lifetime [10].

DWEHC

Distributed Weight-based Energy-efficient Hierarchical Clustering protocol is very much similar to HEED. DWEHC improves HEED by making balanced cluster sizes and optimize the intra-cluster topology using location awareness of the nodes. Both DWEHC also consider residual energy in the process of CH election.

CCS

Concentric Clustering Scheme reduces the energy consumption loopholes in PEGASIS. CCS considers the location of the BS to enhance the lifetime of the network. In CCS, the network is divided into a variety of concentric circular tracks. Each circular track is assigned with a level. The track nearest to the BS is assigned with level-1 and the level number increases with the increase of the distance to the BS. Each node in the network is assigned with its own level.

BCDCP

Base-Station Controlled Dynamic Clustering Protocol is a centralized clustering routing protocol. In BCDCP the cluster formation is done where each CH serves an almost equal number of mobile nodes to balance cluster head overload. At the beginning of cluster setup, the BS receives information on the residual energy from all the nodes in the network.

EDEEC

Heinzelman, proposed LEACH centralized (LEACH-C) a convention that utilize a centralized clustering algorithm and the same steady state protocol as LEACH. SEP (Stable Election Protocol) is proposed in which each sensor node in a heterogeneous two-level progressive system freely chooses itself as a cluster head focused around its initial energy in respect to that of different nodes. Li Qing *et al.,* proposed DEEC (Distributed energy efficient clustering) algorithm in which cluster head is chosen on the premise of probability of proportion of remaining energy and average energy of the system. Simulations demonstrate that its execution is superior to different protocols. B. Elbhiri *et al.,* proposed SBDEEC (stochastic and balanced developed distributed energy-efficient clustering. SBDEEC presents an adjusted and element system where the cluster head election probability is more effective. Besides, it utilizes a stochastic scheme recognition to enlarge the network lifetime. Simulation results demonstrate that this protocol is superior to the stable election protocol (SEP) and the distributed energy-efficient clustering (DEEC) as far as network lifetime. The E-DEEC(enhanced distributed energy efficient clustering) scheme is based on DEEC with addition of super nodes.

DDEEC

Elibhiri *et al.,* proposed a created distributed energy efficient clustering scheme for heterogeneous WSNs. The method of focused around changing rapidly and with more proficiency the cluster head election probability. DDEEC is focused around DEEC technique, where all nodes utilize the beginning and residual energy

level to characterize the cluster heads. To sidestep that every node needs to have the worldwide information of the networks, DDEEC like DEEC assessment the perfect estimation of network lifetime, which is utilized to process the reference energy that every node ought to exhaust throughout each one round. In the technique, the network is sorted out into a clustering hierarchy, and the cluster nodes and transmit the collected information to the base station straightforwardly.

Additionally, the authors have assumed that the network topology is settled and no-changing on time. The contrast in the middle of DDEEC and DEEC is restricted in the articulation which characterize the likelihood to be a cluster head for normal and advanced nodes. simulation results demonstrate that the protocol performs superior to the SEP and DEEC regarding network lifetime and first nodes passes on.

EDDEEC

EDDEEC protocol is proposed for WSNs. EDDEEC is adaptive energy aware protocol which dynamically changes the probability of nodes to become a CH in a balanced and efficient way to distribute equal amount of energy between sensor nodes. We perform extensive simulations to check the efficiency of newly proposed protocol. The selected performance metrics for this analysis are stability period, network lifetime and packets sent to BS. The simulation analysis showed batter results which differentiate EDDEEC more efficient and reliable than DEEC, DDEEC and EDEEC.

iEDDEEC

EDEEC independently elect cluster-heads based on initial energy and residual energy of nodes and does not require any global knowledge of energy at every election round. EDDEEC dynamically adjusts the CHs selection probability and selects the fittest CHs. iEDDEEC modifies the threshold value of a node based on which it decides to be a cluster-head or not along with dynamic CHs selection probability. Thus, iEDDEEC consumes relatively less energy which leads to prolong stability period in comparison to the other protocols; thereby, the number of packets sent to BS are more in comparison to the other selected protocols. It has been observed that stability period of iEDDEEC is 7% and 28% improved than EDDEEC and EDEEC respectively. iEDDEEC maintains average number of cluster-heads equivalent to optimal desired value, therefore, reduces number of direct communications to sink resulting improved stability period. As optimal cluster-heads are elected, the energy dissipation in each round will also be lesser than EDEEC and EDDEEC.

TDEEC

Saini and k.sharma proposed an energy efficient cluster head scheme for heterogeneous wireless sensor networks, which is called Threshold Distributed Energy Efficient Clustering protocol. In this technique, the authors have considered the accompanying supposition: sensor nodes are consistently arbitrarily conveyed in the network. Nodes are position –unaware, i.e., not outfitted with GPS competent antennas.

Protocol Name	Cluster Stability	Delivery Delay	Algorithm Complexity	Energy Efficiency
LEACH	Medium	Very Small	Low	Very Poor
IB LEACH	High	Very Small	Medium	Very High
PEGASIS	Low	Very Large	High	Poor
CSPEA	Medium	Medium	High	High
TEEN	High	Small	High	Very High
SEP	Medium	Very Small	Very Low	Medium
APTEEN	Very Low	Small	Very High	Medium
EECHE	Medium	Small	Low	Very Good
HEED	High	Medium	Medium	Medium
GAF	Medium	Poor	Medium	Medium
DWEHC	High	Medium	Medium	Very High
BSDCP	High	Small	Very High	Very Poor
CCS	Low	Large	Medium	Poor
HGMR	High	Medium	Low	Poor
DEEC	High	Very Small	Very Low	High
EDEEC	High	Medium	Medium	Very High
DDEEC	High	Medium	Medium	Low
EDDEEC	High	Low	High	High
iEDDEEC	High	Low	High	Very High
TDEEC	High	Low	Medium	Medium

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