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A Study on Hierarchical Cluster based Routing Techniques in Wireless Sensor Network

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Abstract - Energy is the scarcest resource in any Wireless sensor network (WSN) as the nodes are battery driven. In most of the applications the sensing area is harsh and remote so in these applications the functions carried out without human involvement throughout the time. Energy conservation is the crucial factor in all wireless sensor networks since battery[1] of the nodes discharges for various functions and communication functionality consumes more energy then other functions. To monitor movements of the endangered species, base station needs to be located at the center and data gathering nodes are attached to the moving objects (nodes become dynamic or movable). To monitor ecological conditions like temperature, humidity, vibration etc no need to move the sensor nodes and they are fixed in the sensing area. Energy saving and improving network life time are the performance measurements in designing any wireless sensor network. Routing strategy selection is very important for proper delivery of packets. Hence need arises for survey of cluster and location based routing protocols[2]. Most of the researchers put their effort on less energy consumed by sensor nodes during communication. This paper provides a survey of various cluster based routing protocols, characteristics and design issues of WSN. The paper is divided as section 1: Introduction of WSN. Section 2: Network Characteristics and Design considerations Section 3: Various Routing Protocols in WSN Section 4: Classification of Cluster Based routing protocols in WSN. Section 5: Comparison between various cluster based routing protocols. Section 6: Conclusion. Section 7: References.

***Key Words*: Cluster Head, Energy drain out, hierarchical protocols, Cluster and non-clustered Network**

1. INTRODUCTION

Sensor network is a structure of sensor nodes and base station. The nodes have integrated functionalities of data sensing, acquiring, processing and transmitting to the BS. These senor nodes are battery driven which are used to agreeably monitor the objects and ecological conditions like temp, vibration, forecast animal monitoring etc. The communication functionality in the network consumes more energy then other functions. All the applications of wsn are run without human involvement throughout the time. In these applications once the battery is drained it is very difficult or impossible to recharge or replace. Hence particular node stops functioning or it will die reducing the network lifetime. So, energy discharging problem is a major [3] issue in any wsn. Hence the researchers put their effort for finding how to minimize the energy consumption and enhancing network lifetime.

Generally the WSNs may be non-Cluster or Clustered as shown in below figures.

1.1 Non clustered WSN:

In non-clustered WSN All the nodes are deployed in the area of interest either uniformly or randomly, each node is independent of other node. Every node sense the data and send directly to destination (BS). If destination is too long the battery drained very quickly and node will die reducing[4] the network life time. Hence nowadays most of the applications employs cluster based WSN.

1.2 Clustered WSN:

In clustered WSN all the senor nodes are connected wirelessly to each other within certain radio range. A head is elected in each Cluster, based on some parameters. The nodes in each Cluster send their data to their respective CH. The CH in each Cluster collects the data from their nodes aggregate [5] it and send to BS as single value. From this a lot of energy can be saved and hence enhancing the network life time.

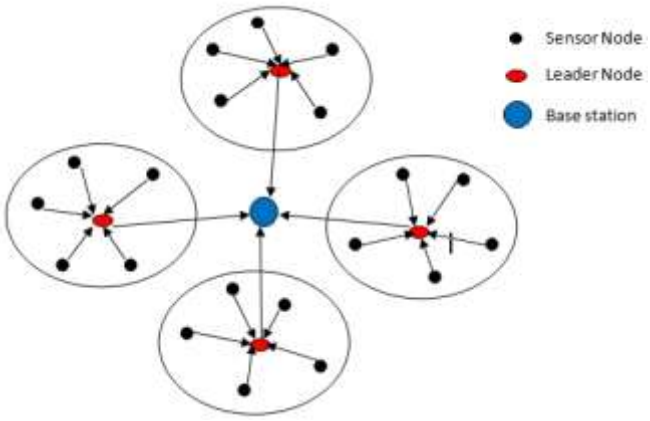


Fig2: Clustered WSN

To design a wireless sensor network it is important to consider Network characteristics and design issues. Some of the characteristics and Design issues are given below

2. NETWORK CHARACTERISTICS AND DESIGN

2.1 Network Characteristics:

- **Deployment of nodes:** All the nodes in the sensing area are [6] densly deployed.
- **Self designed:** The nodes are connected wirelessly and designed autonomously in certain communication radius
- **Data redundancy:** If the number of nodes increases the redundancy [7] increases because all the nodes send their data to a single Sink (many to one).
- **Battery operated sensor nodes:** All the nodes are operated by battery. Battery discharges for various operations
- **Energy, computation and storage constraints:** Each Sensor node has limited energy, computation power and storage space..
- **More to one traffic pattern:** In Wireless sensor networks The data flow is from many nodes to a single Sink
- **Frequent network topology change:** Since the nodes have limited power they will stop functioning after the battery is drained hence the network topology changes.

2.2. Network design considerations:

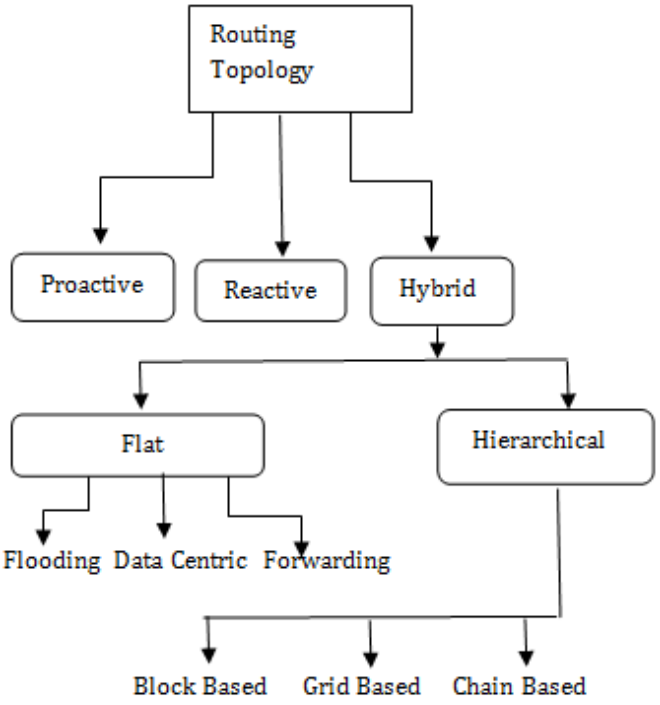
- **Reducing the size of the node and cost:** The size of the nodes should be small for easy deployment since nodes are distributed in harsh and hostile area.. To reduce the cost of whole network [8] the cost of the sensor nodes should be less.
- **Minimum effect;** There should be an minimum effect on the network if any node die or stop functioning due to lack of energy.
- **Scalability:** All the nodes in network should be scalable and respond enough to events.
- **Reliability:** Most of the network are noisy, error prone, and time varying hence the protocols are designed to provide reliable data delivery over to destination.
- **Less energy consumption:** The sensor nodes used in the network should consumes minimum energy to prolong the network lifetime.
- **Adaptability:** The network protocols designed for sensor networks should be adaptable to density and topology changes.

- **Operating environment:** The operating[9] environment should be either indoor or outdoor the nodes in the network may be static or movable attached to the moving objects to collect the data.
- **Channel utilization:** The protocols should be designed in such a way that the nodes utilize communication channels effectively.
- **Data Delivery Model:** The Data delivery model may be Event driven, query driven, continues and hybrid model.
- **Quality Of service:** The quality of service provided to the network must be reliability of data and efficiency in energy.
- **Data Latency and Overhead:** Data latency and overhead considerations are very important parameters while designing routing protocols Data latency caused in multi hop relay and data aggregations.

3. VARIOUS ROUTING PROTOCOLS IN WSN

Routing techniques are used to find path between Transmitter node and Receiving node. In some applications the routes may be predetermined [10] (Proactive) and in some a new route is to be determined (reactive) in some they are combined (hybrid).

According to nature of the network the Routing topologies are categorized as follows.



3.1. *Proactive* routing scheme:

In this topology every node maintains a table which includes the routing information of other nodes. Every node refers this table for routing purposes. Hence the path between source node to destination node is predetermined. The information of the table will be updated periodically[11] according to topology changes. This scheme is suitable for small scale networks.

Examples: Destination Sequenced Distance Vector (DSDV) Protocol, Wireless Routing (WRP) Protocol, Hierarchical State Routing (HSR) Protocol, Source Tree Adaptive Routing (STAR) Protocol, Optimized Link State Routing (OLSR) Protocol, Global State Routing (GSR) Protocol.

Advantage: Minimum path setup latency

Disadvantage: More overhead cost to update routing information periodically.

Not suitable for large and dynamic sensor networks.

3.2. Reactive routing scheme:

In this scheme the path between source node to destination node is not predetermined. This scheme is also called On Demand routing scheme. As the name indicates the node reacts, search and establish a new path whenever it want to send information to destination without referring the routing tables.

Examples: Dynamic Source Routing(DSR) Protocol, Ad hoc On-demand Distance Vector(AODV) Protocol.

Advantages: Minimum routing overhead

Disadvantage: New route establish packet flooding

3.3. Hybrid Routing scheme:

In some applications it is necessary to apply both reactive and proactive schemes. The combination of both reactive and proactive scheme are called Hybrid. For short distance transmission Proactive scheme is employed, Reactive scheme is employed for longer distances. Hierarchical [12] and Flat routing topologies are comes under Hybrid Routing scheme.

Examples: Block Based, Grid Based and Chain Based.

Advantages: Minimizes the effect of disadvantages of both proactive and Reactive schemes.

No need to set up route for short distances.

Less routing overhead.

Disadvantages: Complex.

3.4. Flat Routing scheme:

This type of routing scheme is suitable for the network area having large number of sensor nodes. All the sensor nodes have similar functions for collecting information. In this scheme the nodes doesn't have unique identification due to large number of sensor nodes. Hence data centric technique is employed. The data or information is send to destination through muti-hop communication. Flat Routing scheme is mainly categorized as 1) Flooding 2) Forwarding and 3) Data centric. Again it is subdivided as Flooding & Gossiping, Sensor Protocols for Information via Negotiation(SPIN), Directed Diffusion (DD), Romur Routing(RR), Gradient-Based Routing (GBR), Constrained Anisotropic Diffusion Routing Protocol (CADR), COUGAR and Active Query Forwarding in Sensor Networks (ACQUIRE).

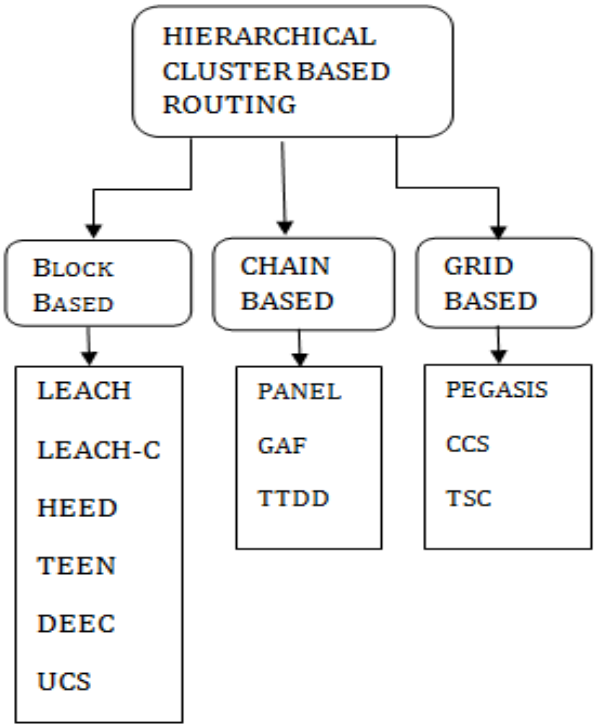
3.5. Hierarchical Routing Scheme:

In this process the nodes having same communication range and radius are grouped to form clusters. The main aim of hierarchical routing technique is to make the nodes consume less energy, less data redundancy. For this a Cluster Head is selected in each cluster the nodes in each cluster send their data to their respective CH. The cluster Head will do some aggregation and reduction of data and forward to BS. Hence a lot of energy can be saved by the nodes. The Cluster Head selection method lowers the energy consumed by each node and hence it lowers the number of transmitted messages prolonging the network lifetime. Number of researches has been carried out on this hierarchical routing technique. Some of the popular hierarchical routing protocols are discussed in this paper which given below.

4. CLASSIFICATION OF HIERARCHICAL CLUSTER BASED ROUTING PROTOCOLS IN WSN:

In clustering technique all the nodes of same communication range are grouped together and are connected each other wirelessly so that they can exchange the information each other in their radius. A head is selected in each group based on some parameters. All the normal nodes are allowed to send their data to their respective head. And head aggregate the data received from different nodes and send to BS as single data. These results in saving lot of energy of sensor nodes and enhancing network lifetime and minimizing the data redundancy. In this paper we discussed some of the popular hierarchical cluster based protocols.

The Hierarchical Cluster based Routing protocols are broadly classified as follows



4 .1. Block Cluster Based Protocol:

4.1.1 Low Energy Adaptive Clustering Hierarchical (LEACH): Heinzaelman. et al. [12] proposed the first well known clustering LEACH protocol. LEACH is considered as the base of all cluster based routing algorithms. Number of protocols have been derived from this LEACH. The main objective of LEACH is to select a cluster Head in each cluster in each rotation so that high energy can be saved by sensor nodes for communication purposes in the network area. The operation of LEACH is divided into two phases 1) Setup Phase 2) Steady State Phase. The Cluster and Cluster Heads are formed in Setup Phase. Transmission functions are carried out in Steady State Phase. All nodes have an equal opportunity to become CHs. Initially [10] a node generating a random number between (0 to 1) to be a Cluster Head (CH) by comparing it with a threshold value TS (n). TS (n) can be calculated using equation given below

$$TS(n) = \{p / 1-p(r \bmod 1/p)\} \qquad \text{If } n \in G$$

Where P is desired percentage of nodes to become CH, r is the present round, *G* is the number of sensor nodes that have not considered in CH election in previous $1/P$ rounds. Nodes with random number lower then TS(n) become CH. Once selected as CH, a sensor node cannot be reselected in a subsequent round. LEACH uses Time Division Multiple Access (TDMA) protocol which avoids multiple collisions between CHs

Advantages:

1) Each node have equal opportunity to become Cluster Head, but a node become CH only once in each round. Hence improving load balancing.

2) LEACH uses Time Division Multiple Access(TDMA) Scheme hence collision between CHs are minimized.

3) Less energy is consumed by each sensor node hence energy efficiency is more.

4) Better Coverage and connectivity 5) Scalability is good 6) Minimum Delay 7) Robustness

4.1.2. Low **Energy Adoptive Clustering Hierarchy-Centralized (LEACH-C):**

It is an improved version of basic LEACH protocol, In LEACH-C Base Station acts as controller of network area all the computations in the network area is done by Base Station(BS). For this each node need to send their information (Position and residual energy) to BS, after receiving the information from all the nodes BS calculates the maximum energy of the node by

comparing it with average energy of all the nodes in the network area. The node is selected as CH if its energy is more then the average energy of the network area. The network's average residual energy can be calculated by using equation

$$Eavg=\sum_{i=1}^{N} Ei \div N$$

Where Ei is residual energy of ith node and N denotes set of sensor nodes

Advantages:1) Energy efficiency is more then LEACH protocol

2) Maximum network life time can be achieved

3) All the computations are done by BS hence a lot of energy can be saved by sensor nodes

Drawbacks*:*

There is no provision in this algorithm to ensure that always maximum residual energy nodes become CHs

4.1.3. Hybrid Energy Efficient Distributed (HEED) Protocol:

O. Younis and Fahmy et al introduced HEED clustering protocol, it is enhanced version of LEACH protocol. The CH selection is not random in this scheme. This protocol provides better load balancing compared to other protocols in this, the Cluster Heads are uniformly distributed. Due to election of more then one Cluster Heads the network consumes more energy which leads unbalanced energy consumption. The sensor nodes having high residual energy are become Cluster Head. When two nodes are within each other's cluster range, the probability of both becoming Cluster Heads is negligible .

Drawbacks:

More number of Cluster Heads are generated in each round hence energy consumed is not balanced and creates massive overheads due to multiple election rounds

$$CHprob=Lprob\times Eresidual \div Emax$$

Where Lprob is an initial percentage of Leader Nodes among all n nodes

Eresidual is the calculated present energy of the node, Emax is the referenced maximum energy (corresponding to a fully charge battery)

4.1.4. Distributed Energy Efficient Clustering (DEEC) Protocol:

Li Qing et al. Proposed the DEEC algorithm. This algorithm is improved version of the HEED protocol which increases the performance of HEED protocol. The authors of this algorithm assumed that nodes would have unequal amounts of energy with the adoptive values. In this the Cluster Heads are elected with a probability based on the residual energy of each node and the average energy of the network.

Drawback: The drawback of the DEEC is that overhead cost is more due to each node needs global knowledge of network.

4.1.5. Threshold Sensitive Energy Efficient Protocol(TEEN)

The Threshold-sensitive Energy Efficient sensor Network (TEEN) [13] was proposed by Anjeshwar et al. This scheme is developed by combining data centric and hierarchical protocols. These protocols are suitable for dynamic networks and time critical applications in hierarchical reactive networks. In this approach, each node broadcasts essential information to the neighboring nodes to elect new Cluster Head(CH). Two thresholds namely soft and hard **thresholds are used by this protocol. These soft and hard** threshold values are used for lowering the number of transmissions. TEEN provides enhanced data delivery rate by transmitting only sensitive data when requested by the user and is used for time crucial applications.

4.1.6. Unequal Clustering Size (UCS):

This protocol is proposed by Soro Et al[14]. In this protocol all the nodes are grouped into unequal sized cluster since unequal sized cluster provides load balancing. Total number of nodes deployed in the network are depend on residual energy and cluster size. It uses multi hop transmission in which each LN Transmits data to its nearest LN in the direction of Base station

Advantages: Less energy consumption compared to LEACH

Number of nodes may vary to maintain balanced energy consumption

Limitations: it is heterogeneous network and Leader Nodes(LNs) are predetermined

It suitable for small range of networks.

4.2. Grid Based Routing Protocols:

4.2.1. Position-based Aggregator Node Election Scheme (PANEL):

This protocol is proposed by Buttyan and Schaffer. To elect node as a node aggregator position information of the node is used. In PANEL, the nodes are positioned[15] in the bounded area partitioned into geographic clusters. The clustering operation is determined before network is deployed, and each node is preloaded with geographic information of its cluster.

Advantages: Ensures load balancing and long network lifetime, Supports asynchronous applications.

Limitations: Clusters are predetermined, Geographic Position information is determine which is not always available

4.2.2. Geographic Adaptive Fidelity (GAF):

This routing protocol also known as directional, geometric, location based routing. In this protocol every node knows its and its network neighbor's position information and source of message is informed about the position of the destination. The sensing area is a grid like structure and all the nodes are deployed according to the geographic position. The grid includes sensors and have similar capacity of data forwarding. Each node monitors the energy consumed receiving and transmitting data. Every node has three states which are

1) Active state—each grid has only one active. 2) Discovery node—New data can be exchanged. 3) The nodes are turned off to save energy.

4.2.3. Two-Tier Data Dissemination (TTDD):

This protocol is proposed by Luo et al. TTDD[16] This type of protocol is suitable for the network where the sink or Bases station is movable This protocol helps to solve mobile sink problems in large networks This uses sensor nodes at grid points for data transmissions. This type of protocol is suited foe event detecting network among irregular data traffic.

Limitations: large latency, Low energy efficiency and Sensor nodes are need to be fixed and location aware.

4.2.4. SLGC:

This clustering algorithm was proposed by Delavar et al**.** In this the network is organized as grid. Center of gravity and threshold of energy is calculated to select Cluster Head(CH) in each grid in each round. SLGC selecting Leader Nodes for next round thereby this LNs minimizes the volume of controlling data for next rounds and inform nodes for sending data into LN of respective round. This method enhances network lifetime by reducing energy consumption Compare to other protocols in SLGC schemes energy utilization is minimum and has better efficiency level.

Draw back: More overheads arises due to large communication ranges

4.3. Chain Based Routing Protocols:

4.3.1 :PEGASIS

PEGASIS is a chain based protocol all the nodes are connected like a chain structure. Data is send to Base station by passing the data from node to node (node transmits to its immediate node). The node number that forwards data to the base station is **r mod N** where r denotes the current round and N denote number of nodes Chain is constructed from farthest node in the network to Base station. Token passing method is used to initialize data transmission and data aggregation is performed at each node except at end nodes.

Advantage: Average energy consumed by each node in each round is minimized and network lifetime has increased up to 300% as compared to LEACH

4.3.2. Concentric Clustering scheme (CCS):

This protocol was proposed by Jung et al. In this scheme Base station location is considered to prolong the network lifetime and enhance the performance. CCS network is divided into concentric circular tracks (level), which indicates different cluster. Track close to the Base station assigned as Level1, similarly level assigned according to the distance increases between the Base station and Track. On each level, nodes from chain inside track, one node is selected as Cluster head (CH). In each level, all nodes transmit their data to nearest node along chain. Nodes which received data fuses its own data and transmit to the next node. Cluster head(CH) of each level transmits data to lesser cluster head. Level 1, Cluster head transmits all data to the Base station. In CCS energy consumption is decreases because the length over which the message can be sending out to the base station from the cluster head is narrowed, conserves energy by separating the network into concentric groups nodes be in touch with their nearest neighbor by using small radio capacity.

4.3.3. Track-Sector Clustering (TSC):

This protocol was proposed by Gautam et al[17]. In this, the network is divided into concentric circular tracks and triangular sectors. It minimizes redundant data transmission and creates shortest distance between Cluster Head (CH) and base station (BS) hence energy is saved. The formation of cluster in TSC takes place in an area under curved form by intersection of circular track and triangular sector.

The execution process can be divided into following phases:

Track Setup: Base station set each node in particular concentric circular track at the geometric center. Total number of tracks depends on node density and location of base station.

Sector setup and Cluster head selection: Base station construct the sectors and select their cluster head.

Chain Construction: By intersection of tracks and sectors chains are formed within each cluster.

Data Transmission: All the member of nodes in the cluster receive and transmit data to neighboring node.

Finally data is transmitted to the base station by multiple hops.

5. COMPARISON BETWEEN VARIOUS HIERARCHICAL CLUSTER BASED ROUTING PROTOCOL:

Name of the Protocol	Type of the Protocol	Energy efficiency	Load balancing	Node distribution	Control packet overhead	Scalability	Inter cluster structure
LEACH	Block Based	Low	Medium	random	Low	Low	Single hop
LEACH-C	Block Based	Low	Medium	Random	Medium	Low	Single hop
HEED	Block Based	Medium	Medium	Random	Medium	Good	Single hop
TEEN	Block Based	High	Good	Random	Low	Good	Multi hop
DEEC	Block Based	Medium	Good	Random	Low	Good	Single hop
UCS	Block Based	Low	Very Low	Random	Low	Medium	Single hop
PANEL	Grid Based	Medium	Good	Random	Medium	Good	Single hop
GAF	Grid Based	Good	Good	Random	Low	High	Single hop
TTDD	Grid Based	Low	High	Random	Low	High	Single hop
PEGASIS	Chain Based	Medium	Good	Random	Medium	Low	Single hop
CCS	Chain Based	Medium	Very Low	Random	Good	Good	Single hop
TSC	Chain Based	good	Low	Random	Medium	Medium	Single hop

6. CONCLUSION

In this paper we proposed introduction of wireless sensor networks, classification of cluster based routing algorithms, Network characteristics , design issues and comparison between various routing Protocols of WSN. From survey it is clear that the main factors of energy consumption is number of transmissions and distance between source to destination by considering these two factors we can reduce the energy consumption of nodes and hence increase the network lifetime.

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