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Clustering Techniques in Wireless Sensor Networks: A Practical Study

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Abstract: ***In recent years, an efficient design of a Wireless Sensor Network has become a leading area of research due to tremendous applications in various fields. A Sensor is a device that responds and detects some type of input from both the physical and environmental conditions, such as pressure, heat, light, etc. The output of the sensor is generally an electrical signal that is transmitted to a controller for further processing. In this context forwarding data from source node to sink node so many efficient energy schemes are available in literature. Among the various methods, clustering methods have gained more importance. In this paper we provided the available various energy efficient clustering schemes along with their advantages and disadvantages.***

Keywords: Wireless sensor networks, clustering, energy efficiency and leach

I. INTRODUCTION

Wireless sensor networks are having many numbers of applications in various fields such as heath sector, agriculture, industry and defense etc. It is a collection of many numbers of sensor nodes in a field for monitoring and tracking the various parameters of atmospheric conditions. In WSN the sensor nodes are used with onboard processor and it will manage and monitors the environment in a specified area. All the deployed sensors sense the environment parameters and forward the sensed data to the base station via all intermediate nodes. At the base station, this data is reviewed, and further action can be taken by sending appropriate control signal information into network.

Basically, a wireless sensor network node consists of four units.

A. Processing unit
B. Communication unit
C. Memory unit
D. Battery

The processing unit is responsible for processing the sensed information by wireless sensor node. Generally, all the wireless sensor nodes are deployed in the communication range. Maximum times the same data sensed by all the nodes in the unit range. So, there may be a chance of getting redundant data and it needs to remove for benefit energy saving purpose in the network. The processing unit in the node removes all redundant data and aggregates to confined information for transmitting to the base station.

The communication unit is responsible for transmitting the sensed data to the base station via all intermediate nodes. For this operation in wireless sensor networks Zigbee communication is used. Nodes will transmit data to the base station by all intermediate nodes.

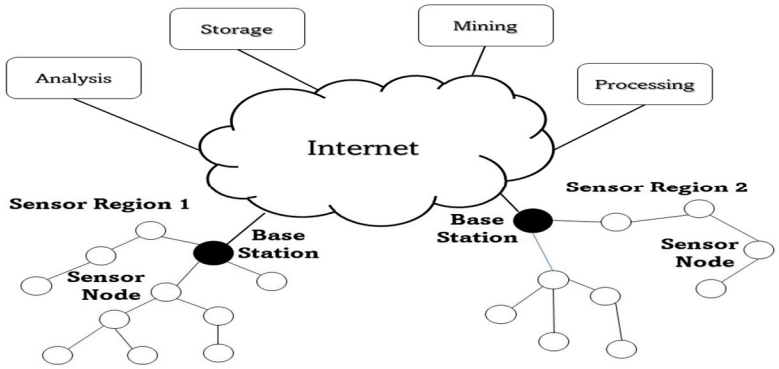

Figure 1: A basic wireless sensor network

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The next main unit is the memory unit and here all the sensed data is stored for temporary purpose and which is very limited in size. The last section of sensor node is battery, and which is very important. Generally, the available battery power is less and due to this network lifetime reducing. So many researchers working on this issue for improving the network lifetime of wireless sensor network.

Apart from the above listed some of the important section is operating system. Here in WSN consists tiny OS maximum cases and which is capable for handling limited operations which are required for this kind of networks.

1) *Applications of Wireless Sensor Network:* There are so many application areas are there and some of them are listed below.

a) Internet of Things (IOT)
b) Monitoring for security, threat detection
c) Environmental temperature, humidity, and air pressure
d) Noise Level of atmosphere
e) Medical sector
f) Agriculture field
g) Landslide Detection
h) Military
i) Navigation etc.

2) *Challenges in Wireless Sensor Networks:* The wireless sensor networks are gaining a greater number of applications still there are some challenges involved here and those are listed below.

a) Quality of Service offered by wireless sensor networks.
b) Security
c) Energy Efficiency of network
d) Network Throughput parameter
e) Performance of the network
f) Node failure
g) Optimization over other layers in the network
h) Large scale of deployment

Among them energy efficiency is the critical parameter we need to take into consideration. Because wireless sensor network nodes battery power level is very less and is not possible to frequent changing of battery every time. So, energy efficiency is one of the important challenges in the network and remaining issues we can solve in some consideration amount.

II. LITERATURE SURVEY

Wireless sensor networks (1) consist of number of sensor nodes randomly distributed in the field. Generally, these sensor nodes having sensing element, communication system, limited processing system, less memory and less power. These networks are having so many constraints such as, lack of proper communication, routing issues, limited energy due to this they are not sustained for long time. Although they are having such limitations, it provides many numbers of services in different fields like military, navigation, health sector and agriculture etc.

In (2) author explained hierarchical protocols are defined to reduce energy consumption by aggregating data and to reduce the transmissions to the Base Station. LEACH is considered as the most popular routing protocol that use cluster-based routing in order to minimize energy consumption.

The author in (3) explained LEACH is a MAC protocol, it contains many advantages like it does not need any control information, it saves energy, it is completely distributed and contain many disadvantages like if cluster head dies then cluster become useless, clusters are divided randomly etc. various improvements are done on LEACH protocol and so there are various version of LEACH protocol.

In paper (4) author explained achieves energy efficiency through a clustering technique with TDMA based MAC layer algorithms and data aggregation method. Analysis performed shows that LEACH uses simple radio propagation and energy models that are unrealistic.

In paper (5) author explained the Leach is one of the best hierarchical protocol and he proposed new approach for cluster head selection.

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To increase the lifetime of network and energy efficiency, we need to change the threshold of electing CH. In other words, we must consider three essential factors: the distance between the node and the BS, the residual energy and the number of neighbor nodes within the cluster range, to calculate the threshold. Therefore, by including distance between the node and the BS, data transmission overhead is minimized.

In paper (6), authors explained the importance of various routing protocols in wireless sensor networks. The importance of hierarchical protocols gained a lot for routing.

Remaining paper explains the various clustering protocols in wireless sensor network and with simulation comparison.

III. CLUSTERING PROTOCOLS IN WIRELESS SENSOR NETWORKS

Wireless sensor networks are aimed to capture the remote location data like temperature, humidity, fire detection and all other atmospheric parameters. In this context forwarding data from source location to destination location like base station we need to depend upon so many routing protocols.

Routing means finding best route to forward the data. In wireless sensor networks these routing protocols are classified into so many categories shown below

1) *Location Based Routing Protocols:* Most routing technique for WSN depends on location information of sensor nodes for estimation of distance between two specific nodes to deduce energy consumption. An example of a protocol that uses this technology is MECN (minimum energy communication network).
2) *Data Centric Based Routing Protocols:* Data transmitted by every sensor node within a particular region has significant redundancy with it. To reduce this redundancy, data centric protocols were developed to select a set of sensor nodes and utilize data aggregation during relaying of data.
3) *Hierarchical Routing Protocols:* Hierarchical routing in WSN involves the arrangement of clusters in form of hierarchy when sending information from the sensor nodes to the base station. Hierarchical routing efficiently reduces energy consumption by employing multi-hop communication for a specific cluster and thus performing aggregation of data and fusion in a way that decreases the number of data carried across the network to the sink. Cluster formation is based on residual energy in the sensor nodes and election of a Cluster head (CH).

Among these categories hierarchical routing protocols are gained more importance in wireless sensor networks. Due to clustered methods, we can reduce the network energy consumption in very low and network lifetime also we can improve significantly. So, researchers placed more focus on to enhance these protocols.

Again, these clustering routing protocols can classify into some more categories shown below.

A. Low-energy Adaptive Clustering Hierarchy protocol (LEACH)

Low-Energy Adaptive Clustering Hierarchy (LEACH), proposed by Heinzelman et al. [7], is one of the best clustering routing protocol for WSNs. The idea of LEACH has been taken as reference for many routing protocols. (7)

The main objective of LEACH protocol is worked on partitioning network into different clusters and after that making some sensor nodes as leaders. These leaders are responsible for transmitting the sensed data to the base station via some intermediate cluster heads(leaders).

The entire operation of LEACH is divided into different rounds, where each round is separated into two phases, the set-up phase and the steady-state phase. In the set-up phase the clusters are formed, while in the steady-state phase data is delivered to the BS. (7)

During the set-up phase, each node checks whether to it become a CH for the current round. This decision is based on the percentage of CHs for the network and the number of times the node has been a CH so far. This decision is made by the node choosing a random number between 0 and 1. The node becomes a CH for the current round if the number is less than the following threshold:

$$t = \begin{cases} \dfrac{P}{1 - P \times \left[r \bmod 1/P\right]} & \text{if } n \in G \\ 0 & \text{otherwise} \end{cases}$$

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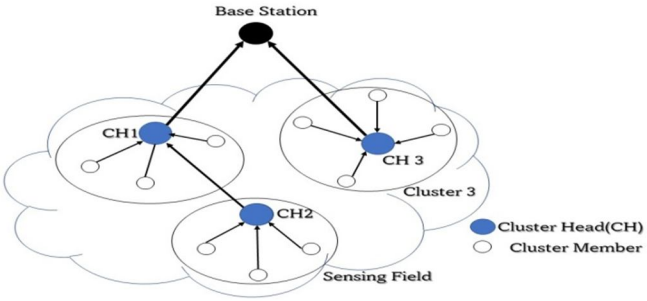

Figure 2: Clustering in Wireless sensor network

Where P is the desired percentage of CHs, r is the current round, and G is the set of nodes that have not been elected CHs in the last 1/P rounds. When a node is elected CH successfully, it broadcasts an advertisement message to the other nodes. Based on the received signal strength of the advertisement, other nodes decide to which cluster it they will join for this round and send a membership message to its CH (7). In order to evenly distribute energy load among sensor nodes, CHs rotation is performed at each round by generating a new advertisement phase based on the above equation. In the steady-state phase, the sensor nodes sense the data and transmit it to the CHs. The CHs aggregate the data coming from nodes that belong to the own cluster and send a free redundant or fused packet to the BS directly. There may be a collision is possible in clusters which leads to data lost. So, to avoid such problems LEACH protocol uses TDMA/CDMA MAC concept to mitigate the inter-cluster and intra-cluster collisions. After first round, the network come backs to the set-up phase again and do another round of cluster head selection and process repeats up to network lifetime.

B. Hybrid Energy-Efficient Distributed clustering (HEED)

Heed protocol is improved version of LEACH protocol. The basic difference between HEED and LEACH is the selection of cluster head mechanism. In LEACH CH selection based on probability of energy of node and whereas in HEED cluster head is selected on two parameters i.e., energy of sensor node and the cost of communication between nodes (8). Here each sensor node is mapped to exactly one cluster. Like LEACH this HEED protocol also worked in different phases and these are

1) *Initialization Phase:* In this phase each sensor node fixes its probability to become cluster head.
2) *Repetition Phase:* In this phase each node repeats to become a cluster head. If any node finds to be no such CH, the elects itself to be a CH and sends the announcement message to its neighbors. Initially sensor node become tentative CH, it changes its status later if it finds a lower cost CH (8).
3) *Finalization Phase:* In this phase nodes either picks the least cost CH or itself becomes a CH. Though it is an improvement over LEACH still it has some disadvantages like more CH are generated than expected and it is not aware of heterogeneity (8).

C. Distributed Weight-based Energy-efficient Hierarchical Clustering protocol (DWEHC)

Distributed weight-based energy-efficient hierarchical clustering protocol (DWEHC) enhanced version of above two protocols. In this protocol each node first locates its neighbors in its enclosure region and then calculates its weight which is based on its residual energy and distance to its neighbors. (9)

The largest weight node in a neighborhood may become a cluster-head. Neighboring nodes will then join the cluster-head hierarchy. The clustering process terminates in some iterations, and this protocol does not depend on network topology or size. (9)

D. Position-based Aggregator Node Election protocol (PANEL)

Position based Aggregator Node election protocol use the node position to elect aggregator node. This protocol ensures load balancing, meaning that each node has nearly the same chance to become aggregator, and it supports intra and inter cluster routing allowing sensor-to aggregator, aggregator-to-aggregator, base station-to-aggregator, and aggregator-to-base station communications. (10)

The operation of PANEL relies on

The assumption that in this protocol is nodes are aware of their geographic positions. This means that some positioning mechanism needs to be implemented in the network in order to support the network. (10)

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IV. PERFORMANCE OF SIMULATION

To analyze the performance of the above stated clustering protocols we taken some important measurable parameters of wireless sensor networks into account. For simulation we used MATLAB simulator. The same network parameters are considered for entire above four protocols. The simulation is carried out for various rounds to find out the lifetime of the network.

TABLE 1: Simulation parameters for MATLAB

Parameters	Value
Simulation Area	500 X 500
Number of Nodes	150
Number of Rounds	100
Base station location	(150,150)
Channel type	Wireless Channel
Energy of Node	5J
Transmission energy, ETX Receiving energy, ERX	50 50
Simulation time	6 Minutes
Sensing range	30 meters
Packet size	500 bytes

The performance metrics of wireless sensor network are coverage area, energy consumption, packet delivery ratio and throughput etc. For this work we performed simulation for packet delivery ratio, energy consumption and throughput for several rounds to the same network with the above four protocols.

1) *Energy Efficiency:* This is the parameter it will decides the network lifetime. If energy efficiency is very low that network offers long life. The obtained results shows that LEACH protocol offers very less energy efficiency compared to HEED, DWEHC and PANEL protocols. DWEHC clustering protocol offers very high energy efficiency whereas remaining two protocols given some moderate energy efficiency.
2) *Packet Delivery Ratio:* It is one of the best parameters to identify the network efficiency is packet delivery ratio which means the total number of data packets which are received at destination to the total number of packets which are transmitted at the source node. The packet delivery ratio of above four clustering protocols after getting results shown that which are in the following descending order LEACH, HEED, DWEHC and PANEL, respectively.
3) *Throughput:* This parameter also decides the network efficiency. Throughput defines the how much data can be transmitted in each time frame and it is measured in bits per second or data per second. The throughput of the network is very high in LEACH compared to remaining protocols.

V. CONCLUSION

Wireless sensor networks are having tremendous applications in various fields like industry, agriculture, marine and ocean etc. Energy efficiency can be reduced by best routing protocols. In literature so many protocols existed but more importance gained by clustering routing methods only. Still more research is going in this area of wireless sensor network only. In this paper we more focused on wireless sensor network capabilities, issues, applications and more over the importance of clustering routing protocols is given after performing simulation in MATLAB. There are so many simulators are available like NS2, NETSIM and OMNET. In my future work we will propose enhanced version of clustering protocols.

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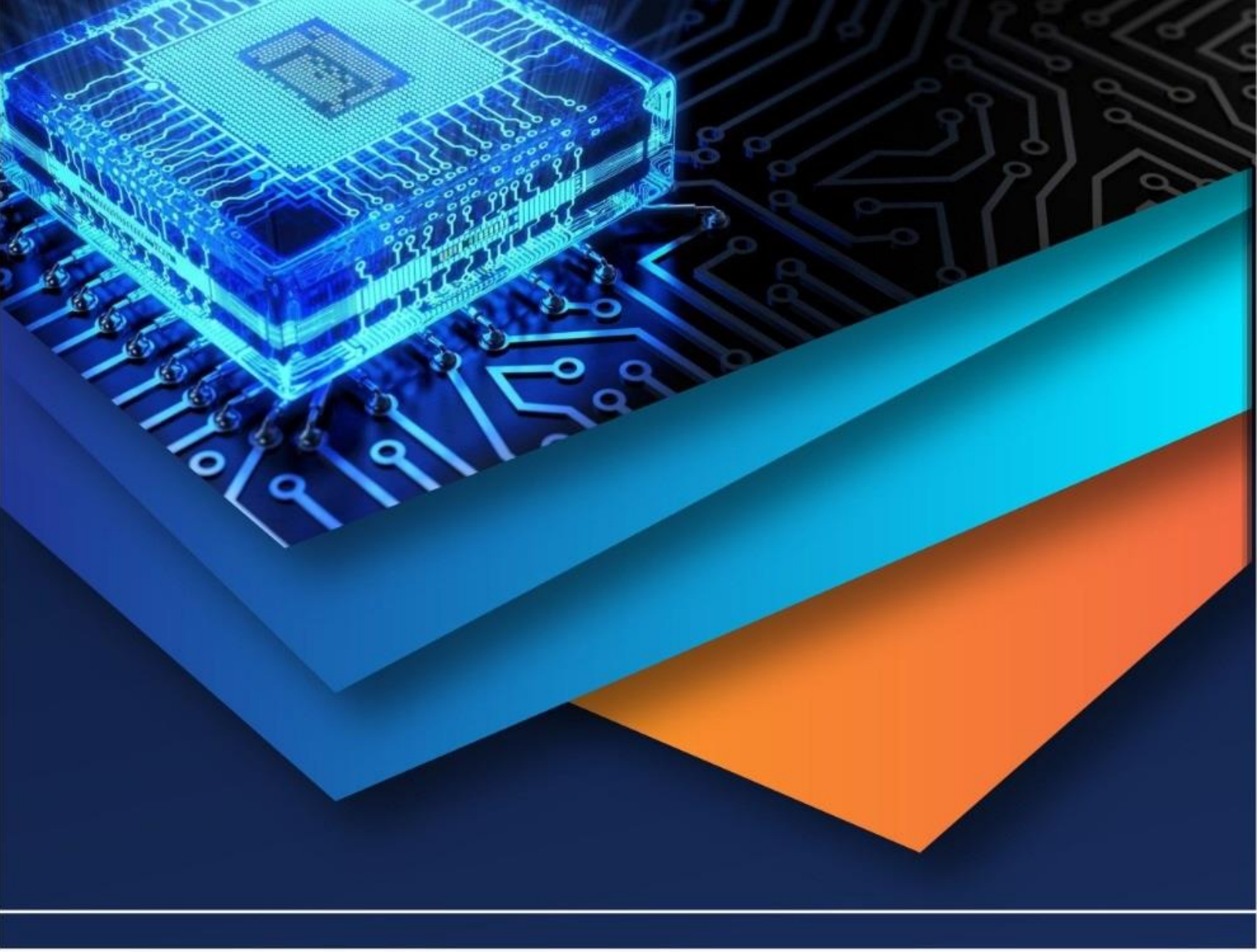

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