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Comparative Analysis of Algorithm for Cluster Head Selection in Wireless Sensor Network

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***Abstract*—** One of the challenging issues to be studied in WSN is its energy saving so as to extend lifetime. The primary goal of node clustering is network preprocessing that is used to obtain information and limit energy consumed. To support high adaptability and better accumulation of information data, sensor nodes are often grouped into disconnected, non overlapping batches, groups of nodes called clusters. Clusters design hierarchical WSNs which incorporate adequate performance of finite reserves of sensor nodes and thus enhance network lifetime. In this paper different clustering algorithm are compared having different cluster head selection approach. Our paper presents review of different energy efficient cluster head selection algorithms in WSNs.

Keywords- *clustering algorithms, cluster head (CH), wireless sensor networks (WSN).*

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I. INTRODUCTION

Wireless sensor network is a communication technology which used in many applications for transmitting data from source node to destination node. A wireless sensor network consists of collection of thousands of sensing devices called as sensors. The sensor node has ability of sensing the environment as well as transmitting data. The huge number of sensor within a wireless sensor network is distributed to monitor and detect the environmental and physical condition i.e. Sound, vibration, temperature. It may also be used in many application like military, battlefield, monitoring, wild animal monitoring, health care applications and also commercial application such as target tracking etc. The sensor node is made up of the hardware components such as CPU, battery power, memory, ADC, sensing devices. The working procedure for sensor node is as firstly, the environment is sensed, secondly the processing for sending the message is done and lastly communication with the B.S or sink is done.

The sensor nodes are simulated by various other algorithm and protocol for properly handling the traffic and delay of data transmission from sensor node to destination node. Thee sensor nodes have limited energy, which has given rise to clustering. Energy efficiency is an important factor to extend the lifetime of sensor node.

Architecture of WSN is classified as layered architecture and clustered architecture. In layered architecture the sensor nodes communicates with B.S in i-hops whereas in clustered architecture the sensor nodes are arrange in group called cluster and the member nodes communicate only with their respective cluster head and the cluster head with the B.S. Cluster head acts as a leader for its remaining members performing intra cluster data arrangement, data sending and so on. Cluster head aggregates data from other cluster members and sends to sink as single packet, thus Cluster Head reduces data transmission to base station.

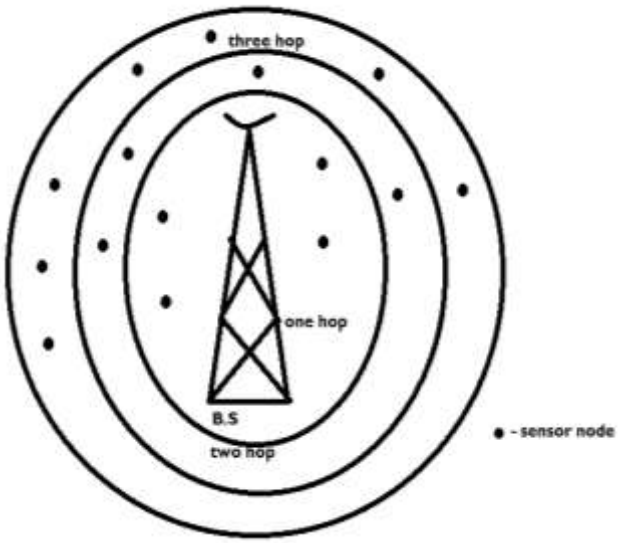

Fig1: layered architecture

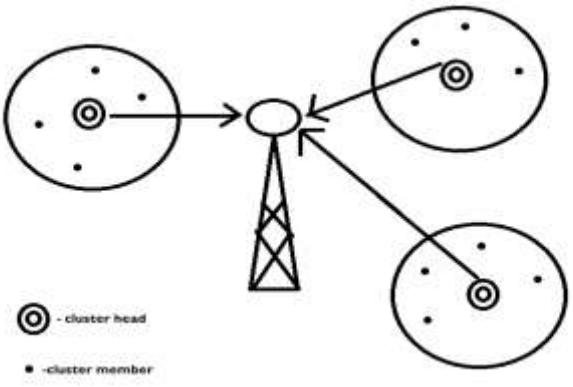

Fig2: clustered architecture

In wireless sensor network clustering is divided into two classes – homogeneous and heterogeneous

In the first class i.e. Homogeneous environment all sensor nodes have equal level of energy, thus when a sensor node is elected as Cluster Head it performs its job of leader among the members for its whole lifetime. In this environment Cluster Head is selected randomly as the energy level of all nodes are same and protocol coordination (leach) perform excellently well in this environment.

In the second class in the heterogeneous environment all the sensors have different energy level and altogether different functions. Thus the data transmission through Cluster Head in this type of clustering is still a research issue.

Different routing protocols are needed for sending data between sensor nodes and the base station for communication. Routing protocols can be classified as

- Based on modes of functioning and types of target application like pro-reactive, reactive and hybrid.

In pro-reactive protocols the nodes switch on their sensors and transmit data to B.S through a predefined route, e.g. LEACH. In reactive protocol, if there is abrupt change in sense attribute beyond some predetermine threshold value, the nodes react immediately. It is basically used in tie critical application e.g. TEEN. In hybrid protocol it makes use of both pro-reactive and reactive protocol. It first computes the entire route and then improve route at time of routing e.g. APTEEN

- Based on participation style of node like direct communication, flat and clustering protocol.

In direct communication any node can send data to B.S directly. In large networks sensor nodes drain their energy very fast and hence its scalability is very low e.g. SPIN. In flat protocol nodes that need to transmit data first finds a valid route and then transmit data to B.S. nodes that are closer to B.S drain their energy very fast and thus its scalability is average e.g. rumor routing. In clustering protocol, the total area is divided in number of cluster and each cluster has a cluster head and the cluster head communicates with the B.S all the other nodes in cluster send data to their respective cluster head e.g. TEEN.

- Based on network structure as data centric, herarical and location based protocol.

Data centric are query based they depend on naming desired data and thus eliminate redundant transmission. B.S sends query to certain area for information and waits for reply from nodes of that particular area. Depending on query sensor collects particular data from area of interest. This particular information is transmitted to B.S and thus reduces number of transmission e.g. SPIN. In herarical routing higher energy nodes are required to process and send information to B.S and low energy nodes perform the sensing of area of interest e.g. LEACH, TEEN, and APTEEN. In location based protocols some information about the location of sensor nodes is required. This information about the location of senor nodes can be obtained from GPS signal or radio signal and with this information an optimal path is formed e.g. GEAR

Wireless sensor network involve many clustering techniques such as LEACH, HEED, TEEN, PEGASIS etc. for reducing energy consumption and increasing the life time of sensor nodes. The clustering technique involves grouping of sensor nodes and then selecting a Cluster Head from the cluster member. The Cluster Head provides data aggregation and also data communication between sensor nodes. The Cluster Head is selected by certain algorithm aggregate data from member of cluster and then send it to base station from where the user can approach it.

II. SCOPE OF PROBLEMS

For transmitting data by using hardware node or by using simulation algorithm to simulate. It has been observed that the following important parameters are mainly noted down in WSN.

1 Lifetime
2. Energy
3. Throughput
4. Delay
6. Jitter

To overcome the problem in WSN. We can design different protocol and algorithm for data transmission. In this research work we analyze different algorithm for selection of cluster head used in WSN.

III. RELATED WORK

Network lifetime predictability is an important requirement for type of WSN used in high reliable application [1]. They have addressed the issues of predictability; high energy first (HEF) algorithm is proved as an optimal cluster head selection algorithm that extends network lifetime under ideal conditions. Performance study is done to compare performance of HEF with that of LEACH, and investigate

feasibility of HEF. Cluster head selection, prolonging network lifetime and scalable data aggregation are the key issues [2]. Distributed energy efficient clustering is used. The approach is hybrid, CH are probabilistically selected based on residual energy. Quasi stationary nodes are assumed where nodes are location unaware and have equal significance. Key feature is that it exploits availability of multiple transmission power level at sensor nodes. Based on this, HEED protocol is introduced which terminates constant number of iteration. In [3] a new energy-efficient dynamic clustering technique for large scale-sensor networks to minimize energy spent in both intra and intercluster communication. The paper also proposes routing algorithm that is both energy efficient and power aware so as to prolong network lifetime. The solution is conducted in 2 parts to verify proposed dynamic clustering and routing algorithm resp.to verify energy efficiency of dynamic clustering it is compared with LEACH and HEED. Two sub gradient algorithm, i.e. Fully distributed algorithm and partially distributed algorithm are proposed to compute an optimal routing flow to maximize the network lifetime [4]. The two algorithms are proposed and simulated, their graphs are studied and different extension to original problem is considered and shown how sub gradient approach is used to obtain distributed algorithm. In [5] designing of energy aware algorithms for extending lifetime of sensor nodes is performed. Simulation for LEACH algorithm and particle swarm optimization (PSO) algorithm is done and graphs are plotted for

(1) No of nodes vs. average residual energy

(2) No of nodes alive vs. simulation time

(3) Simulation time vs. no of cluster head

(4)Average energy consumption vs. no of nodes, and it concluded that cluster head election using PSO approach increases life time of sensor nodes. Different algorithms are defined for data aggregation with an aim to obtain qualified information and limit the energy consumption [6]. A comparison between Data relay K-means, fuzzy C-means, Vornoi based Genetic clustering algorithm is made for following parameters :

(1) Based on clustering properties

(2) Based on cluster head abilities

(3) Based on cluster head selection process, and results are analyzed. WSN is a technology about acquiring and processing information and transmission of data requires routing protocol [7]. Since energy is limited in WSN LEACH protocol is researched and improved. LEACH and improved LEACH algorithm are studied and simulated and a comparison is made from the graphs of

(1) Life cycle of network,

(2)Energy consumption of network, between the two algorithms is declared. In [8], the author presents improved version of LEACH protocol which aims to reduce energy consumption in wireless sensor network and prolong lifetime of network. Improve LEACH is provided by improving election strategy of cluster head nodes based on residual energy, distance from base station and nos. of consecutive round .comparison graph is plotted for LEACH, EECH, and proposed protocol. In [9] Energy-Aware Clustering (EAC) algorithm is proposed to prolong network lifetime and it also introduce energy factor for cluster head selection and distance factor for non-cluster head to select its cluster head. Comparison of network lifetime of LEACH and EAC is done. In [10] the author proposes a new clustering algorithm based on energy, density, location information to sink. Makes cluster head for entire network distribution more reasonable and more balanced energy. Improve LEACH is proposed and compared with original LEACH by plotting graph for:

(1) No. of survival nodes

(2)Node residual energy, thus the researchers in this field has done many researches to extend lifetime and conserve energy of sensor nodes.

IV. OVERVIEW OF DIFFERENT CLUSTER HEAD SELECTION ALGORITHM IN WSN

Mostly used clustering algorithms are**: -** LEACH, PEGASIS, HEED, HEF, EAC, TEEN

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

LEACH is a hierarchical based clustering algorithm of routing protocol for WSN that form node cluster based on signal strength. These clusters have a devoted node with extra advantages called as cluster head (CH). These CH aggregates data from member nodes and sends it to base station, and also creates and manages TDMA schedule.

The operation process for LEACH is split into rounds and each round has the following steps;

[1] Set-up phase:

- cluster head selection:

The decision of a node to become a CH is independent of other node. This decision is made by taking into consideration the fact that, when the node did last became a CH. Depending on required number of CH in network, a threshold equation for CH selection is given

$$T(n) = \frac{P}{1-P*(r \bmod 1/P)} \quad \text{.....[6]}$$

If n € G

T (n) = 0, otherwise

Where,

P=desired percentage of CH

r= current round

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G=class of nodes that have not been CH for last 1/P rounds

Every node in G chooses a random value between o and 1 and if number is less than threshold value it is elected as CH for the present round.

- advertisement phase:

  Node elected as CH informs the other member node in cluster about its election as CH through advertisement packet.

- cluster setup phase:

  The member node informs the CH that it has become member of that particular cluster with join packets containing their Id's.

[2] Steady phase:

- Routine creation:

  After reception of these messages CH creates TDMA routine and broadcast TDMA table to all member nodes.

- data transmission:

  The member node sends their data to CH during allocated TDMA slot.

Thus when all data is received from member nodes the CH sends it to sink or B.S. LEACH reduces energy consumption and enhances lifetime by efficiently utilizing the resources, distribution of load uniformly and rotating the CH to accomplish balance energy consumption.

Drawback:

- CH selection is random and doesn't take in consideration the energy consumption.
- CH are not uniformly distributed, CH can be located at edge of clusters.

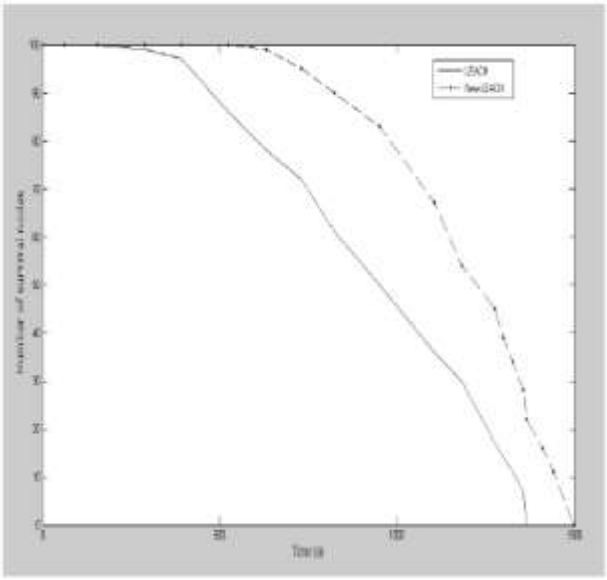

Fig 3: number of survival nodes (graphs are result plotted from [10])

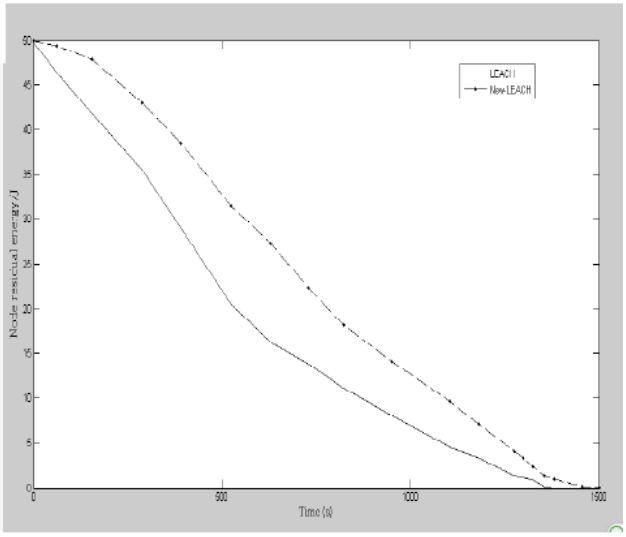

Fig 4: Node residual energy (graph is result plotted from [10])

B. PEGASIS (Power Efficient Gathering in Sensor Information System) ALGORITHM:

A chain of sensor nodes is made instead of clusters; all nodes in this chain can transmit as well as receive data from their neighboring nodes. The node that start transmitting is called as end node, the other node starts receiving data and sends data to neighboring node after aggregating data. The process continuous till last node in chain is elected as leader node.

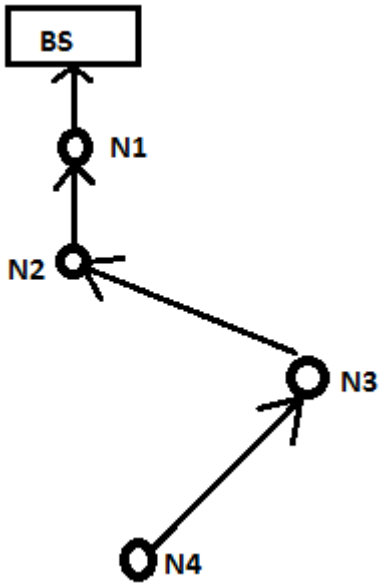

Fig 3: flow of data in chain to B.S

C. HEED (Hybrid Energy Efficient Distributed) ALGORITHM:

HEED algorithm is different from LEACH in cluster head (CH) selection. In LEACH CH selection is random whereas in HEED CH selection is not random. Performance of cluster formation is based on hybrid combination of two

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features.one of the feature depend on residual energy and the other is the communication cost of intra cluster. The residual energy of elected cluster head is relatively high than member node. Probability that anode becomes CH is

$CH_{pob} = C_{prob} \quad E_{residual} / E_{max}$..... [2]

Where,

$E_{residual}$ = estimated current energy

$E_{max = reference}$ maximum energy

CH_{prob} value is not allowed to drop down below a threshold that is elected to be inversely proportional to E_{max}. Every node goes through numerous iteration until it finds a CH. If CH is not selected then node elects itself as CH and sends messages to neighborhoods nodes. Two types of status are send by the sensor nodes to the neighboring nodes i.e. tentative status and final status. If CH_{prob} <1, then node is tentative CH and then changes to regular node. If CH_{prob} = 1, then nodes become CH.

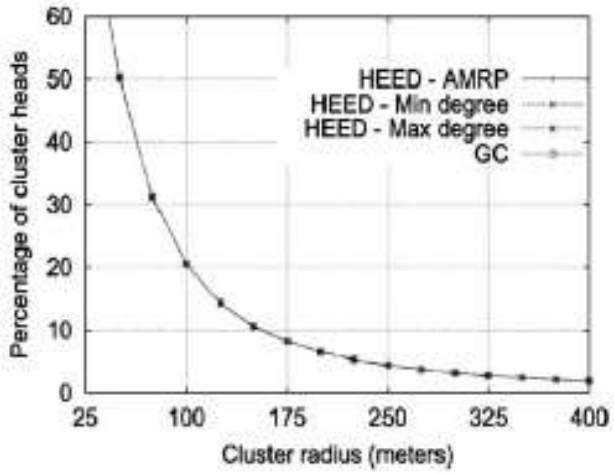

Fig 5: (a)

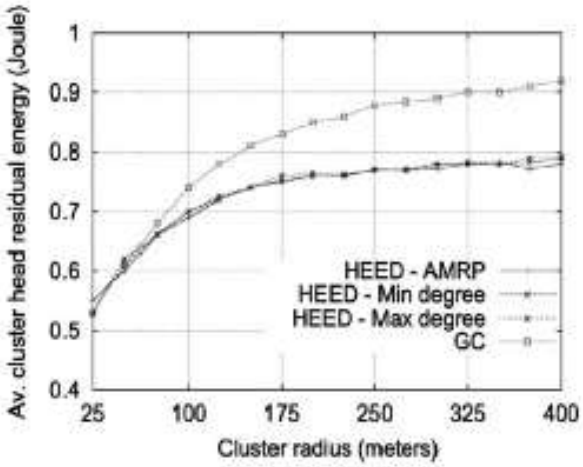

Fig 5: (b)

Fig 5: characteristics of selected cluster head (a) percentage of cluster head (b) average residual energy per cluster head (graphs are simulation result of [2])

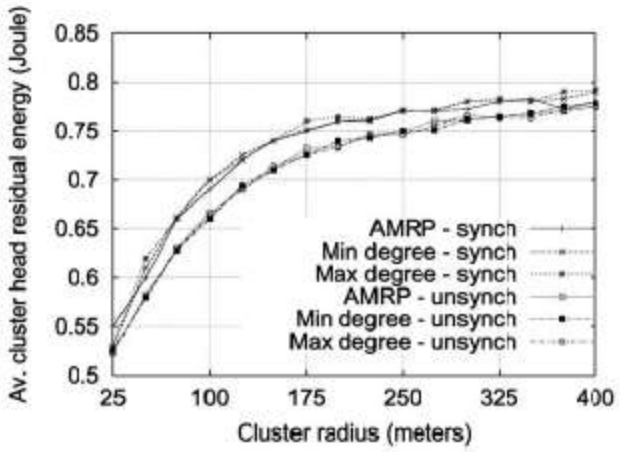

Fig 6: HEED average cluster head energy for synchronized and pseudo synchronized nodes (graph is simulation result of [2])

D. EAC (Energy Aware Clustering) ALGORITHM:

EAC recommends energy element for cluster head selection and distance element for non-cluster head to select its cluster head. In EAC time is divided in round and each round consist of two aspects: formation of cluster and transmission of data. In first aspect of each round, every node announces its residual energy value and a sensor node is elected as cluster head if its energy is higher than neighboring nodes energy. The node that has highest energy sends join message to neighboring nodes and then the cluster head creates TDMA schedule and sends this schedule to cluster members. In the second aspect the each node sends the information data to the cluster head in its allotted TDMA schedule. When all information data is received by the cluster head from member nodes it uses non-persistent CSMA to send information data to base station or sink.

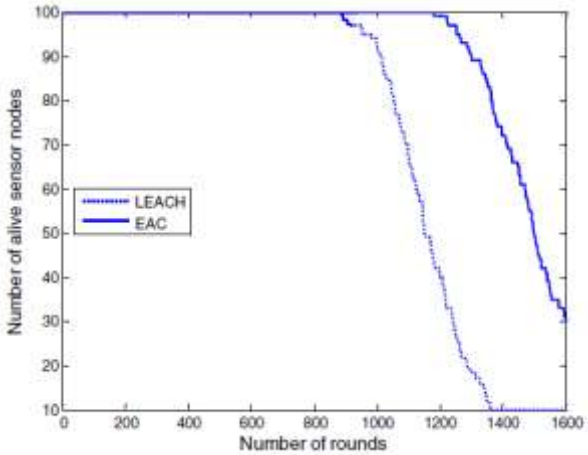

Fig 7: comparison of network lifetime (graph is a simulation result of [9])

E. TEEN (Threshold Sensitive Energy Efficient Sensor Network) ALGORITHM:

The CH propagates the following to its members:

- *Hard Threshold (HT):* This is a threshold value for the sensed features.

- *Soft Threshold (ST):* This is a small change in the value of the sensed features which triggers the node to switch on its transmitter and transmit.

The nodes sense their environment continuously. The first time a parameter from the features set reaches its hard threshold value, the transmitter is switched on and sends the sensed data. The value that has been sensed is stored in an internal variable, called Sensed Value (SV). The nodes will transmit data in the current cluster period only when the following conditions are true: The current value of the sensed feature is greater than the hard threshold. The current value of the sensed attribute differs from SV by an amount equal to or greater than the soft threshold.

Drawback:

- If the thresholds are not attained, then the nodes will never communicate.

- Transmission of message requires more energy than sensing of data.

V. CONCLUSION

We have surveyed different routing protocols algorithms along with advantageous and disadvantageous comparison with LEACH protocol. We have found that some energy efficient algorithms increases the network lifetime and also consumes energy in routing. Although every effort has been made to provide complete and accurate state of the art survey on energy efficient clustering algorithms as applicable to WSNs.

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