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A Survey on Research on Clustering In Homogeneous and Heterogeneous Wireless Sensor Networks

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ABSTRACT: Cellular Sensor Network is usually a network of little battery driven sensing devices (referred to as sensing nodes), with the capacity of sensing the physical parameters like temperature, humidity, pressure, motion, etc. from its environment of deployment and statement it to a central node called foundation station. These nodes collaborate with one another to satisfy their job. As the power source is usually constrained in WSNs, it must be used correctly. Clustering is among the methods which are becoming used effectively to reduce energy dissipation in WSNs. Clustering protocols result in improvement in the intake of energy, lower cost of conversation in the network and improved effectiveness. In this paper, we present an excellent grained study on LEACH centered hierarchical clustering protocols, specifically in a heterogeneous network where in fact the energy of the nodes is usually different and at the end we present assessment in tabular type, based on base station area, contribution, advantages, drawbacks and improvement accomplished with the compared protocols.

Keywords: Clustering, energy efficient, lifetime, heterogeneous; hierarchical, wireless sensor network

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I. BACKGROUND

The sensor network consists of constrained nodes in terms of processing power, memory unit, and battery source and communication bandwidth. The basic components of sensor node are sensors, memory unit, processing unit, power supply unit and actuator [1].Among all these energy is of prime importance because of its hostile place of deployment; nodes cannot be recharged or replaced easily. Clustering is one of the techniques being used heavily to provide stability, load balance and conserving the energy dissipation of the nodes. A large number of clustering techniques have evolved in time starting with LEACH [2]. A lot of survey on energy efficient clustering techniques has already been done as in papers [3] [4] [5] [6]. Our focus is on heterogeneous protocols along with the level of performance improved in comparison to the existing state of art protocols. We have also emphasized on the location of the base station whether it is inside the sensing field or outside. Heterogeneous sensor networks are the networks where nodes have different initial energy.

The rest of the paper is organized as follows: Section II presents the network and the basic energy model used by most of the protocols, Section III discusses the most fundamental protocol in clustering called LEACH and thereafter Section IV discusses various hierarchical protocols for heterogeneous networks, Section V provides the summary table and finally Section VI concludes the survey.

II. NETWORK AND THE ENERGY CONSUMPTION MODEL

We assume a heterogeneous network of wireless sensors where the maximum transmission power of each node is uniformly distributed in $[E_0, \alpha E0]$, where E_0 is the minimum transmission power of sensor node and α is a constant such that $\alpha>1$. We also assume that the nodes have always data to send and every common node in the cluster will send *l* bits of message to its cluster head in every round.

III. LEACH

LEACH [7] [2] is a self-organizing, adaptive protocol, which uses the concept of random selection of cluster heads. It uses a simple radio model as shown in figure 1. LEACH uniformly distributes the energy load among all the nodes in the network. LEACH locally aggregates the data and compresses it so as to minimize energy dissipation from cluster to the base station. LEACH consists of two phases: Setup Phase and Steady Phase.

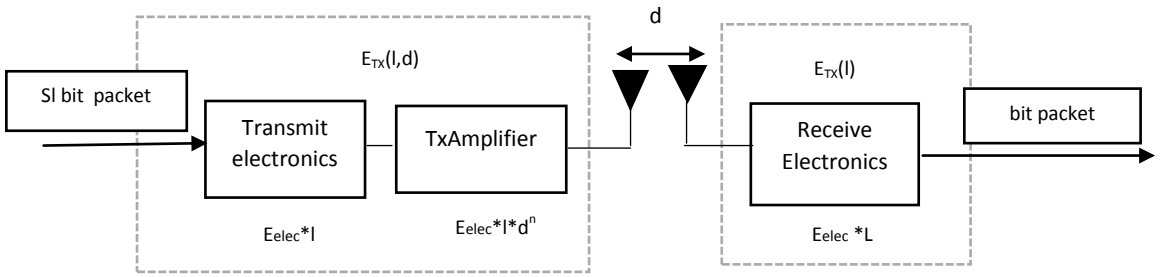

Fig 1: Simple radio model

Setup phase: It includes the concept of "rounds" in the set-up phase. This phase can also be called as cluster formation phase. All nodes begin with the same initial energy. A node selects a random number between 1 and 0.If the number is less than the threshold, the node is selected as a cluster head for the current round. For a particular node, threshold is calculated for a particular round by following equation (1)

$$T(n) = \begin{cases} \dfrac{p}{1 - p * \left(r \bmod \frac{1}{p}\right)}, & if\ n \in G \\ 0, & otherwise \end{cases}$$

The nodes that become the cluster head (CH) during round 0 cannot become the cluster head again in next 1/p rounds. The nodes that become the cluster head for a particular round, then transmit an "advertising message" to all the other nodes in the network that have not been the CH for that particular round. All non CH nodes turn their radio links on, so as to receive the advertising message sent from the CH and select the CH to which they will belong, for this round.

Steady Phase: After the formation of clusters, CH will now allocate the time slot to each nodes, each node will now be sending their data to the CH in their allocated time slot. The CH node turns on their antenna until all the nodes have sent their data. After receiving all the data from the nodes, CH now aggregates and compresses the data within the cluster. Now CH will send the fused data to the base station.

IV. HIERARCHICAL PROTOCOLS FOR HETEROGENEOUS SENSOR NETWORKS

In the last decade lots of clustering protocols have evolved based on different criteria's of cluster head selection, number of clusters, hierarchy and types of nodes:

- No. of clusters:-The total number of clusters to be taken is a critical parameter and it is usually a preset parameter.
- Nodes and cluster head mobility: -As nodes are geographically, distributed, dynamic and mobile in WSN which forces clusters or nodes in a network need to be continually maintained.
- Node types and role: - In a homogenous network all the nodes initially have the same energy and some subsets of nodes are designated as cluster heads. In heterogeneous network nodes have different energy and according to which their roles are designated. Some protocols haveintroduced the idea of advance node, super nodes and normal nodes, relay nodes and have defined their work too.
- Multilevel levels: -In several published approaches now a days the concept of multilevel cluster hierarchy is used which leads to attaining more energy conserving network.

4.1 AD-LEACH (Advanced LEACH)

AD-LEACH [8] is an energy efficient technique for heterogeneous network which takes static clustering into consideration. It inherits the properties of LEACH [2] and DEEC [9].Takes CH selection criteria from DEEC and architecture of protocol from LEACH protocol. This protocol forms a network with small and permanent static clusters with following contributions:

- Minimized Complexity: small clusters are easy to maintain.
- Minimized power consumption: power transmission of nodes reduces as they have to relay message or data in smaller area.

According to the constraint and accessibility of the area the shape of the clusters is decided as rectangle or square Cluster heads are selected based on their residual energy. After the selection of CH, total energy and network lifetime are needed by each node in the cluster.

Each cluster contains separate AD-LEACH protocol which runs in parallel with the other neighboring clusters. Base station provides the information by broadcasting it to the each node. CH then allocates the time slots to the client nodes to send the data within the allocated time slot. The current round is calculated in the following equation (2)

$$\overline{E}(r) = \frac{1}{N_{cls}} E_{total}\, 1 - \frac{r}{R}$$

TABLE 1: Symbols and their meaning in ad-leach

Symbol	Meaning
Etotal	Total Energy of the network
E_{round}	Average energy of the network at round r
r	Current round
R	Network life time in terms of rounds
N_{cls}	Total Number of nodes in current cluster

4.2 DEEC (Distributed Energy Efficient Clustering) [9]

Distributed energy efficient clustering scheme is designed for heterogeneous wireless sensor network, uses an adaptive approach in order to control the energy consumption of nodes. DEEC works similar to LEACH by selecting a number between 1 and 0 and calculating the threshold value shown in equation (4).However DEEC takes the ratio of initial and residual energy level of the nodes to select the cluster head.

Despite of having entire knowledge of the network at each round it uses the reference energy that each node should transmit during a particular round which is calculated by estimating the ideal value of network lifetime. In this way the nodes with higher initial and residual energy will have greater chances to be elected as cluster head. This protocol makes the energy of the network well distributed for the running process. Like AD-LEACH, in DEEC protocol all the nodes need to determine the total energy and the network lifetime. All this information is known to the nodes as the base station broadcast the information.The probability of a node for becoming a cluster head is 1 cycle by the base station. Duty cycle is also set by the base station in the set-building phase.

4.3 Modified DEEC [10]

In Modified DEEC the performance is further improve due to varying power level while communicating with intra-cluster and inter-cluster nodes and allowing only those nodes to participate in cluster head selection whose energy level is above a threshold value. The scaling factor for varying power level is calculated as in the equation (3)

$$Scale\ factor = \frac{Area\ of\ Network\ field}{area\ of\ the\ cluster}$$

4.4 MG-LEACH (Multi Group Based LEACH) [11]

Multi Group based LEACH makes use of redundant information for selecting the cluster head, which contributes a major fraction of energy depletion in wireless sensor network. It consists of 3 phases: Set building phase, Setup phase and Steady phase.

Set building phase is an extra phase in this protocol. This phase is initiated before set up phase. Nodes to be deployed are divided into subgroups depending upon their location. After every 'x' rounds these groups are created by the base station. The groups alternate i.e. one at a time per set duty.

4.5 TL-LEACH (Two Level LEACH) [12]

TL-LEACH proposed the idea of transmitting the information by using two level of hierarchy. It preserves the key features of LEACH like randomization, adaptability and data fusion. Differs from LEACH in set-up phase in which nodes can be primary CH, secondary CH or simple node, which contributes to minimize energy consumption and increase in lifetime of WSN. Instead of transmitting information directly from the client nodes to the cluster head, it uses an intermediate level called as secondary cluster head to relay the information to the primary cluster head i.e. top cluster level and the primary cluster head then transmits the information to the base station.

In each cluster there is only one primary cluster, but it could have one or more than secondary clusters depending upon the density of the nodes. In this protocol before sending an advertisement message to the primary cluster head each secondary cluster must decide to which primary cluster it belongs to and likewise each client node must decide to which secondary cluster head it belongs to by using an appropriate message.

4.6 V-LEACH [13]

In Vice LEACH each cluster consists of a CH, which is used to transmit the information received from members to base station. A vice CH acts as a CH when old CH dies and sensor nodes which gather the information or data and transmit them to CH.

As the CH is responsible for doing most of the work, its probability of getting down is higher than the other nodes in the cluster. V -LEACH has overcome from this deficiency of LEACH and has introduced a Vice CH besides a main cluster head. In this way there is no need of selecting again and again the CH for the cluster and the energy of the network is also preserved.

4.7 LEACH-R [14]

LEACH -R basically uses a relaying node called R node between cluster head and base station which is distant from the cluster head. This algorithm is also divided into two phases: setup phase and steady phase. In setup phase instead of using the threshold which is used in LEACH, it uses an advanced threshold to decide which node to become the cluster head is specified in the following equation (4)

$$T_r(n) = \begin{cases} \dfrac{p}{1 - p * \left(r \bmod \frac{1}{p}\right)} \left[\delta p + \dfrac{(1-\delta p) E_{residual}}{E_0}\right] if n \in G \\ 0 \qquad\qquad if\ n \notin G \end{cases}$$

TABLE 2:Symbols and their meaning in leach-r

Symbol	**Meaning**
P	Percentage of Cluster heads
R	Current round
G	Set of nodes what have not been cluster heads in last 1/p rounds
Eresidual	Residual energy of node
E_o	Initial energy of the node
$T_r(n)$	Threshold of node n at round r
Δ	Number of consecutive rounds during which a node has not been CH

By using this advanced threshold the nodes with the higher residual energy will have greater chances to be elected as the cluster head. So the cluster head selection is directly based on the residual energy of a particular node. After the selection it broadcasts messages to every cluster and the base station which is at a distant.R node is chosen among the cluster heads. Node with the highest lambda value will get selected as R node and the remaining nodes will send their data to the selected R node after the collection of data. R nodes are responsible for transferring data from cluster head to base station n vice versa.

4.8 TDEEC (Threshold Distributed Energy Efficient Clustering) [15]

Communication is held from high energy nodes to low energy nodes. The high energy nodes are generally elected as the cluster heads and the low energy nodes are used to send their data to the high energy nodes. In VAP-E the partitioning of the network is done only once that too after the value of optimum number of cluster heads to be formed is determined. After virtually portioning the area the algorithm is applied within the network to select the cluster head.

TDEEC is based on DEEC. It uses the concept of normal, advance and super nodes. Like in traditional LEACH, if a number selected by node is less than the threshold then the node will become the cluster head. Likewise in TDEEC it selects the cluster head by taking the ratio of residual energy and average energy of that node at a particular round 'r'.

4.9 VAP-E(Virtual Area Partitioning)[16]

The entire region is divided into different sub regions depending upon the energy of the n odes. Generally the communication is held from high energy nodes to low energy nodes. The high energy nodes are generally elected as the cluster heads and the low energy nodes are used to send their data to the high energy nodes. In VAP-E the partitioning of the network is done only once that too after the value of optimum number of cluster heads to be formed is determined.After virtually portioning the area the algorithm is applied within the network to select the cluster head.The total energy of the network is calculated using equation (5)

$$E_{total}\,(r) \approx E_{initial} - (r-1)E_{round}$$

TABLE 3: Symbols and their meaning in vap-e

Symbol	**Meaning**
Etotal(r)	Total energy of the network at round r
Einitial	Initial Energy of the node
Eround	Energy dissipated in a round during the reorganization of the cluster

4.10EEMHR [17]

Energy efficient multi-level heterogeneous routing protocol (EEMHR) uses a variable threshold for selection of cluster head. This threshold is defined as ratio of live nodes during current node to total nodes. It has also proposed k level of hierarchy with an improvement of 17% over SEP [18] and MCR [19] protocols. This protocol has significant improvement in network lifetime, better stability, and better distribution of CHs optimally.

TABLE 4: Comparative study of different protocols

PROTOCOL	**ADVANTAGES**	**DISADVANTAGES**	**CONTRIBUTION**	**LOCATION OF BS**	**COMPARED WITH**	**IMPROVEMENT ACHIEVED**
AD-LEACH	Stable	Level ofheterogeneity is two	Each node broadcast message reduced power because it has to cover small area	Centre of the sensing field	LEACH DEEC	Reaches threshold in around 3150 rounds, FND after 2300 rounds and LND after 5000 rounds
DEEC	Nodes with high residual energy have high chances of becoming cluster heads.it increases the network lifetime, especially the stability period. Suitable for multilevel heterogeneous network	All the nodes communicate at same power level	Takes into account the residual energy during cluster head selection process	Centre of the sensing filed	LEACH – E SEP	Under two level heterogeneity. It obtains 20% more number of rounds than LEACH – E Under multilevel heterogeneity. It obtains 15% more number of rounds than SEP
Modified DEEC	Intra cluster and inter cluster communication are at different power level. Nodes can participate in cluster at selection only if its energy is more than threshold value	Level of heterogeneity is only 2.	Varying power level based communication at inter cluster and intra cluster level.	Centre of the sensing filed	DEEC	Number of packets transmitted to the BS: modified DEEC gives a substantial improvement of 19.3% Last node: improvement of 12.5%

MG - LEACH	Improves energy efficiency by exploiting the redundancy in data transmission. Enhance the network lifetime to a great extent than the leach	Extra overhead for selecting cluster head.	The redundant information that are collected by normal nodes in the sensing field is discarded by cluster head before forwarding it to BS	Centre of the sensing filed	LEACH	For initial energy 0.51, MG-LEACH first node dies after 1481 rounds and last node dies after 1023 rounds For initial energy 0.21, first node dies after 3100 rounds and last node dies after 4062 rounds
TL - LEACH	Better distribute of energy and load among the sensor nodes. Less number of nodes is required to transmit further distance to the place station, which increase the energy of the network.	Selection of two CH is a burden (primary and secondary cluster heads). In the middle stage, the rate of death of nodes is high.	Promotes localized computation at two different levels	Outside the sensing field	LEACH	Increases delivery of packet by 20% and lifetime of network by 30%
V - LEACH	Number of messages created by the V – leach is less than the messages created by the original leach. No need of selecting the new cluster head every time which saves the time and energy of the network	Extra processing for selection of vice cluster head.	Vice cluster head takes the responsibility when cluster head is dead.	Outside the sensing field	LEACH	Marginal improvement over LEACH, as number of messages generated are less, energy is conserved in V-LEACH
LEACH - R	Residual energy of the nodes is considered during the selection of cluster head. Uses relying	Additional cost in choosing relay nodes	Relay node will aggregate the data receiving from cluster heads and transmit the fused data to BS	Outside the sensing field	LEACH	Saves around 20% of energy than leach

	node between base station and cluster head which reduces a load on a particular node to retrieve and send data to the base station					
TDEEC	Improves stability and energy efficiency.	Overhead on cluster head selection is high.	Multiple level of heterogeneity (level 3)	Center of the sensing field.	SEP,DEEC	Lifetime increases by 20% for m=0,a=3.
VAP-E	Does not need global information to calculate the energy. It balances the load among clusters.	It does not take into account the distance.	Equal distribution of cluster heads. Improvement over LEACH and LEACH-E.	Outside the sensing field.	LEACH-E	VAP-E delivers 10% more packets than the LEACH-E.
EEMHR	Variable threshold based CH selection.	Overhead on cluster head selection is high.	Variable threshold based CH selection and optimal selection of CH.	Center of the sensing field.	SEP,MCR	Improvement by 17%.

V.CONCLUSION

The major concern while designing a routing protocol for a wireless sensor network is energy dissipation rate. The objective is to reduce the energy dissipation and hence increase the life time of the network. Energy dissipation can be reduced by reducing the number of transmission of data and that also to long distance. In this paper we have surveyed hierarchical heterogeneous protocols and discussed their advantages and disadvantages along with the contribution made by the paper. A large number of protocols have already been developed however still more work needs to be done, especially keeping in view the heterogeneity of the network and mobility of the base station.

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