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A Review on Energy Efficient Clustering-Based Routing Protocols for Homogeneous and Heterogeneous Wireless Sensor Networks (WSNs)

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Abstract:

In recent years, Sensor networks are rapidly growing research area in Wireless Communication. Sensor network is a densely deployed wireless network of low-cost, low-power, small in size and multifunctional sensor nodes which can be used in various applications like health, temperature, humidity, environment monitoring, military, home, gathering and sensing information in inhospitable locations etc. However, the radio transmission and reception consumes a large amount of energy. This is one of the major issue in Wireless Sensor Network (WSN) because of the limited battery power in the network. Lifetime of the sensor nodes depends on the lifetime of power sources of nodes. So to maximize the lifetime of sensor nodes, it is advisable to distribute the energy dissipated throughout Wireless Sensor Network (WSN) in order to increase the overall network performance. Routing Protocols plays an important role in conserving energy in Wireless Sensor Networks (WSNs). In this paper, main focus is on survey of energy efficient cluster-based routing protocols for homogeneous as well as for heterogeneous WSN.

Keywords — **Copper Slag, Phosphogypsum, Strength, Durability.**

I. INTRODUCTION

Recent technological advancement in micro-electronic-mechanical systems (MEMS), wireless communication and digital electronics technologies have enabled the development of low-cost, low-power and multifunctional sensor nodes that are tiny in size in WSN [1]. These smart sensor nodes are deployed over a geographical area for monitoring the physical phenomena. WSNs become widely useful in variety of applications such as environment monitoring, field surveillance, military and civilian applications [2].

WSN is different from traditional wireless communication network such as cellular networks and mobile ad-hoc networks (MANET) [3]. WSNs have unique characteristics such as higher node density, higher unreliability of sensor nodes and prone to failure which show many challenges in development of WSN. Sensor nodes in WSN are tiny in size but include three basic components- a sensing unit, a processing unit and a wireless unit. In addition, a power unit called battery supplies the energy needed by device as shown in fig.1. Sensor node may include location finding system to find out their position and a mobilizer to change their location or configuration. Sensor nodes must

- Consume extremely little power
- work in high volumetric densities
- have low production cost
- be autonomous and adaptive to the environment

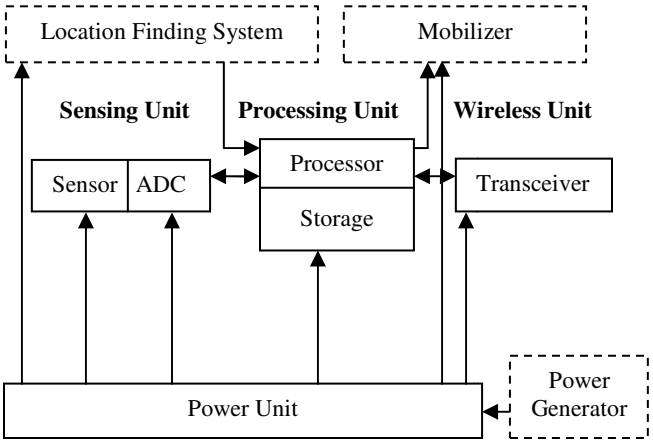


Fig. 1 Components of Wireless Sensor Node

Fig. 2 represents Sensor Network Model consists of one sink or Base Station (BS) and large number of sensor nodes deployed over a geographical area called Sensing field [2].

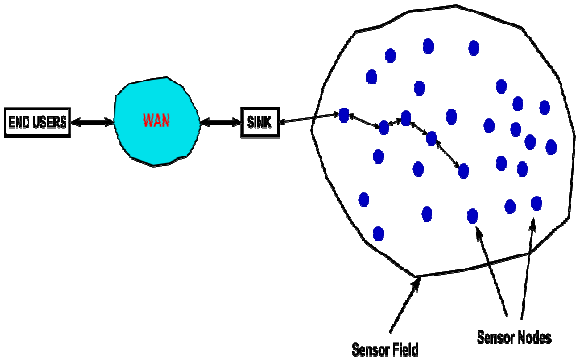


Fig. 2 Working of WSN

A variety of protocols were proposed for extending the lifetime of WSN and for routing the correct information to the sink or BS. In this paper, various Energy-Efficient Cluster-Based Routing Protocols for WSN are discussed. This paper is organized in following way: Section 2 describes the Energy Efficient Clustering Structures in WSN. Section 3 describes Energy-Efficient Cluster-Based Routing Protocols for Homogeneous and Heterogeneous WSN. Section 4 includes conclusion of survey and section 5 consists of references.

II. ENERGY EFFICIENT CLUSTERING STRUCTURES IN WSN

Clustering is to be the best way for achieving energy efficiency. Number of protocols is designed in this regard. Clustering [4] is a mechanism in which sensor nodes are grouped together to form clusters and select one sensor node as a Cluster-Head (CH). All the sensor nodes called cluster members send sensed information to their CH in the specific allotted time slot by CH. Fig. 3 [5] shows that all the sensor nodes use that allocated time slot to communicate with their respective CH. Now CH aggregates all received information from cluster members & send compressed data to Base Station. Fig. 4 shows the communication between Base Station & Cluster-Head (CH).

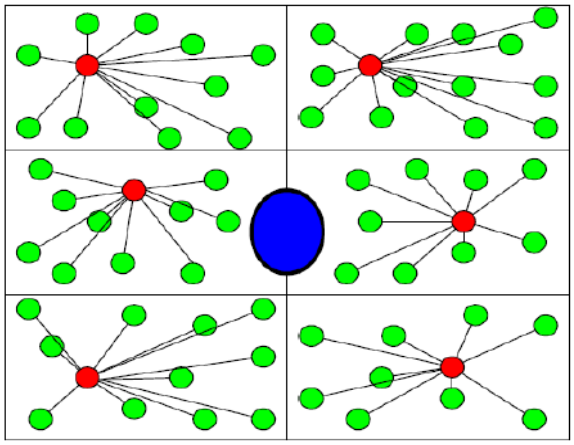


Fig. 3 Communication between CHs & Cluster members

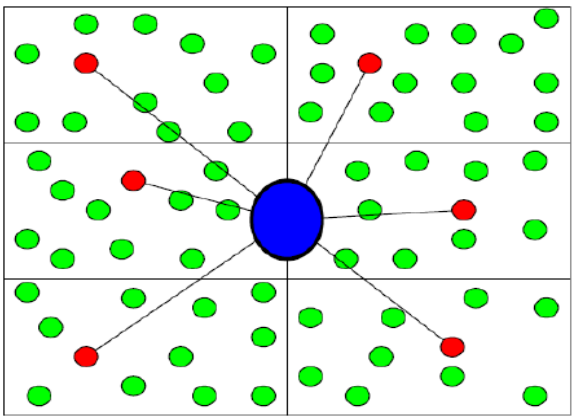
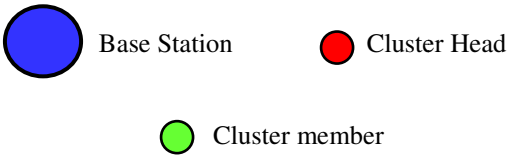


Fig. 4 Communication between Base Station & CHs



As shown in Fig. 5, Clustering helps in setting the route within the cluster and therefore it also reduces routing overhead and topology maintainence overhead. In Cluster-Based Hierarchical Model data travel from lower clustered layer to higher clustered layer. This model is better than one-hop or multi-hop model beacause it reduces the travel time & latency. In this model, only CHs involves in data aggregation whereas in multi-hop every intermediate node involves in data aggregation. So, Cluster-Based Hierarchical Model is more suitable for time critical applications.

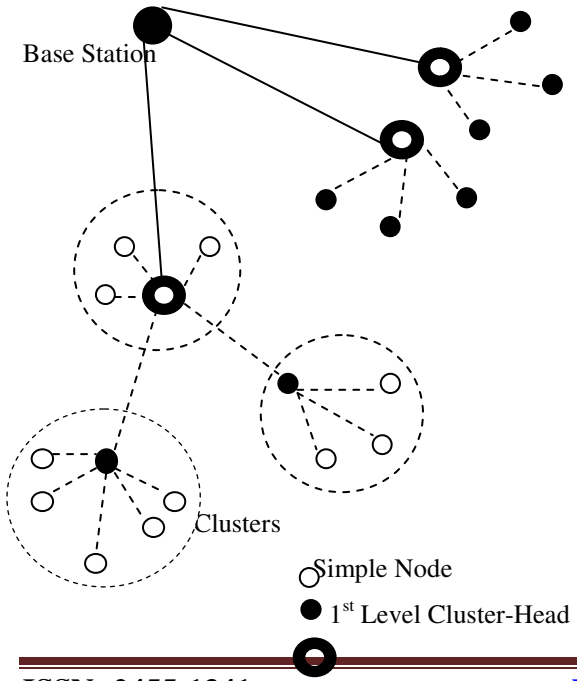


Fig. 5 Cluster-Based Hierarchical Model

Clustering can be done with sensors having same initial energy levels are termed as Homogeneous WSN as well as with the sensors having different initial energy levels are termed as Heterogeneous WSN [14]. Low Energy Adaptive Clustering Hierarchy (LEACH) [6], Threshold Sensitive Energy Efficient Sensor Network Protocol (TEEN) [7], Hybrid Energy Efficient Distributed Clustering (HEED) [8], Power Efficient Gathering in Sensor Information Systems (PEGASIS) [9] are the examples of Homogeneous Protocols. Homogeneous network may become heterogeneous after some rounds because protocols dissipating different amount of energy from every single node in real sensor. Stable Election Protocol [10], Disributed Energy-Efficient Clustering Protocol [11], Developed Disributed Energy-Efficient Clustering Protocol [12], Enhanced Disributed Energy-Efficient Clustering Protocols [13] are the examples of Heterogeneous Protocols.

III. ENERGY EFFICIENT HIERARCHICAL CLUSTER ROUTING ALGORITHMS

A. Homogeneous Protocols

1) Low Energy Adaptive Clustering Hierarchy (LEACH): LEACH [4], [6] is a homogeneous energy efficient clustering based routing protocol for WSNs that was proposed for reducing the power consumption. In LEACH, all the nodes organize themselves into local clusters & then randomly selects a few nodes as CHs. Clustering task is rotated between the nodes to evenly distribute the energy load. All the non cluster heads called cluster

members transmit their data to CH. After receiving the data from all the cluster members, cluster head aggregates the original data and compressed it into the data that carry only meaningful information. Cluster-Head used the direct communication to transmit the data to Base Station (BS). The operation of LEACH is divided into two rounds & each round has mainly two phases : (a) Set-Up Phase (b) Steady State Phase.

(a) Set-Up Phase: Set-Up phase is used to organize the network into clusters. A sensor decides to become a CH based on desired percentage to become a CH, current round and set of nodes that have not been a CH in previous 1/P rounds. A sensor node chooses a random number between 0 & 1. Let the Threshold Value T(n) :

$$T(n) = \begin{cases} \dfrac{P}{1 - P(r \bmod \frac{1}{P})} & \text{if } n \in G \\ 0 & \text{otherwise} \end{cases}$$

P is the desired percentage of CH, r is current round and G is the set of nodes that have not been a CH in previous 1/P rounds. After the nodes have selected themselves to be CHs, it broadcasts

an advertisement (ADV) message. All non CH sensor nodes must keep their receivers ON to hear the ADV. CH node create a TDMA schedule that tells each cluster member exactly when to transmit its data so that intra-collisions are prevented.

(b) Steady State Phase: It is used for data aggregation, compression & transmission to BS. To reduce energy dissipation, radio of each non CH node is turned off until is allocated transmission time. LEACH aggregate the data in order to reduce the total amount of data & then send them to sink.

Disadvantages of LEACH: (i) LEACH is not applicable to network deployed in large region because it uses single-hop routing. (ii) The idea of dynamic clustering brings extra overhead eg. Head change, ADV etc. that can increase the energy consumption. (iii) LEACH does not guarntee good CH distribution & assume CH consume same amount of energy.

2) Threshold Sensitive Energy Efficient Sensor Network Protocol (TEEN): TEEN [7] is protocol in which nodes are grouped into cluster with each led by CH. The nodes within a cluster send their data to CH. The CH send fused data to higher level CH until data reaches to the sink. After the clusters are formed, CH broadcasts two threshold value to sensor nodes called (i) Hard Threshold (H_T) (ii) Soft Threshold (S_T).

Hard Threshold : It is minimum possible value of attribute beyond with node switches ON its transmitter & send the sensed data to its CH. With the help of Hard Threshold, nodes transmit only when the sensed attribute is in range of interest, thus reducing the numberof transmission.

Disadvantage of TEEN: The main drawback of TEEN is that if the threshold are not received, the sensed data is not transmitted & the user does not get any data from the network.

3) Hybrid Energy Efficient Distributed Clustering (HEED): HEED [8] periodically selects CHs according to set of two parameters. The first parameter is residual energy of each node and second parameter is node degree or cluster density i.e number of neighbour. In HEED, each sensor node defines the probability of becoming a CH ie CH_{prob} as follows:

$$CH_{prob} = C_{prob} \times \frac{E_{residual}}{E_{maximum}}$$

C_{prob} is initial percentage of CHs in LEACH is predefined, $E_{residual}$ is the residual energy in sensor node & $E_{maximum}$ is the maximum energy corresponding to completely charged battery.

Disadvantage of HEED: In HEED, selection of CHs deals with only subset of parameters, which can impose limitation on one system.

3) Power Efficient Gathering in Sensor Information Systems (PEGASIS): PEGASIS [9] is a chain based protocol which rather forming clusters, forms chain from sensor nodes so that each node sends & receives from a neighbour & only one node is selected from that chain to send data to BS. When a sensor node dies due to less battery power, construction of chain is continous by passing the failed or died sensor. In this protocol, nodes only communicate with their nearest neighbour, taking turns to communicate with BS. PEGASIS increase the lifetime of each node & as a result increase the lifetime of the network.

Disadvantage of PEGASIS: PEGASIS requires dynamic topology adjustment in order to know where to route the data. Such adjustments can introduce overhead for highly utilized networks and affect the protocol functionality.

B. Heterogeneous Protocols

Heterogeneous WSNs are preferred than Homogeneous WSNs because Homogeneous protocols are poorly performed in Heterogeneous [14] enviornment. Lower energy nodes are died more quickly than higher energy nodes because homogeneous clustering protocols are unable to treat each node discriminatorly in terms of energy discrepancy.

1) Stable Election Protocol (SEP): SEP [10] is developed for two-level heterogeneous WSNs, which include two types of nodes according to initial energy i.e. advanced nodes & nornal nodes. E_o is the initial energy of Normal nodes and m is the fraction of Advanced nodes which have a times more energy than normal nodes. Number of advanced nodes are mN equipped with initial energy of $E_o(1+a)$ and (1-m)N are normal nodes equipped with initial energy E_o. Total initial energy for two-level heterogeneous network is :

$$E_{total} = N(1-m)E_o + mN\,(1+a)E_o$$

The weighted probability for normal & advanced node in two-level heterogeneous network is as:

$$P_{nrm} = \frac{P_{opt}}{1+am} \quad , \quad P_{adv} = \frac{P_{opt}\times(1+a)}{1+am}$$

P_{opt} is the optimal probability, P_{nrm} is the weighted probability for normal node & P_{adv} is the weighted probability for advanced node. SEP prolongs the stability period & higher throughput.

Disadvantage of SEP: This protocol is reliable for two-level heterogeneous WSNs but not fit for widely used multi-level heterogeneous WSNs, which include more than two types of node.

2) Distributed Energy-Efficient Clustering Protocol (DEEC): DEEC is focussed to deal with multi-level heterogeneous WSNs. In DEEC [11], CHs are selected by a probability based upon the ratio between the residual energy of each node & the average energy of the network. DEEC adjust the rotating epoch of each node according to initial & residual energy. The nodes having high initial & residual energy will have more chances to become CHs rather than low energy nodes. In this way, DEEC prolong the network lifetime, mainly stability period defined as the time interval before the death of first node. The total initial energy for multi-level heterogeneous WSN :

$$E_{total} = \sum_{i=1}^{N} E_o(1 + a_i) = E_o(\,N + \sum_{i=1}^{N} a_i\,)$$

The weighted probability for normal & advanced node in two-level heterogeneous network is as:

$$P_{nrm} = \frac{P_{opt}}{1+am} \quad , \quad P_{adv} = \frac{P_{opt}\times(1+a)}{1+am}$$

P_{opt} is the optimal probability, P_{nrm} is the weighted probability for normal node & P_{adv} is the weighted probability for advanced node. In DEEC, we replace

the P_{opt} with weighted probability for normal & advanced node for two-level heterogeneous network is:

$$p_i = \begin{cases} \frac{P_{opt} \times E_i(r)}{(1+am) \times \bar{E}(r)} & \text{if } s_i \text{ is the normal node} \\ \frac{P_{opt} \times (1+a) \times E_i(r)}{(1+am) \times \bar{E}(r)} & \text{if } s_i \text{ is the advanced node} \end{cases}$$

p_i is the averge probability to be a CH for two-level heterogeneous network. This model is extended for multi-level heterogeneous network & p_i is :

$$p_i = \frac{P_{opt} \times N \times (1 + a_i) \times E_i(r)}{(N + \sum_{i=1}^{N} a_i) \times \bar{E}(r)}$$

Disadvantages of DEEC: In DEEC , when energy level of advanced nodes become down, it choose advanced nodes continuously to select as CH and they die more quickly than normal nodes and in this case they consume more energy and effect stability of network.

3) Developed Distributed Energy Efficient Clustering (DDEEC): DDEEC [12] uses same method for estimation of average energy in the network & CH selection algorithm based on residual energy as implemented in DEEC. Difference between DDEEC & DEEC is centered on expression that defines probability for normal and advanced nodes to be a CH. Nodes having high initial & residual energy will have more chances to become CHs rather than low energy nodes. DDEEC remove the disadvantage of DEEC by releasing advanced nodes after reaching a certain energy threshold. DDEEC makes some changes to save advanced nodes from being punished over and again. DDEEC introduces threshold residual energy given below :

$$TH_{REV} = E_o (1 + aE_{disNN} / E_{disNN} - E_{disAN})$$

When energy level of advanced & normal nodes falls down to the limit of threshold residual energy then both types of nodes use same probability to become Cluster Head. Therefore, CH selection is balanced & more efficient. Threshold residual energy Th is given as in:

$$p_i = \begin{cases} \frac{P_{opt} \times E_i(r)}{(1+am) \times \bar{E}(r)} & \text{for Nml nodes, } E_i(r) < t\square res\square old\ residual \\ \frac{P_{opt} \times (1+a) \times E_i(r)}{(1+am) \times \bar{E}(r)} & \text{for Adv nodes, } E_i(r) < t\square res\square old\ residual \\ c\frac{P_{opt} \times (1+a) \times E_i(r)}{(1+am) \times \bar{E}(r)} & \text{for Adv, Nml nodes, } E_i(r) \geq \text{threshold residual} \end{cases}$$

The value of TH_{REV} is written as $TH_{REV} = bE_o$ where:

$$b = (1 + aE_{disNN} / E_{disNN} - E_{disAN})$$

c is a real positive variable which control directly the clusters head number.

4) Enhanced Distributed Energy-Efficient Clustering Protocol (EDEEC): EDEEC [13] uses the same views of probabilities for CH selection depends on initial energy, remaining energy levels of nodes & average energy of the network as proposed in DEEC. EDEEC considers three types of sensor nodes [13] with different energy levels i.e. normal nodes, advanced nodes, super nodes. The probability used for CH selection is p_i & P_{opt} is reference probability. EDEEC uses different value of P_{opt} for normal nodes, advanced nodes & super nodes. The probability for these three types of nodes is:

$$p_i = \begin{cases} \frac{P_{opt} \times E_i(r)}{(1+m(a+m_o b)) \bar{E}(r)} & \text{if } s_i \text{ is the normal node} \\ \frac{P_{opt} \times (1+a) \times E_i(r)}{(1+m(a+m_o b)) \bar{E}(r)} & \text{if } s_i \text{ is the advanced node} \\ \frac{P_{opt} \times (1+b) \times E_i(r)}{(1+m(a+m_o b)) \bar{E}(r)} & \text{if } s_i \text{ is the super node} \end{cases}$$

EDEEC is an adaptive as well as energy aware routing protocol. This protocol increases heterogeneity by including concept of super nodes.

IV. CONCLUSION

Due to limited energy resources, energy conservation is one of major challenge in design of protocol for WSNs. In this paper, discussed various energy-efficient cluster based routing protocols that

have been designed to optimize the energy consumption for homogeneous as well as heterogeneous WSNs. This paper concluded that heterogeneous protocols performed better than homogeneous protocols. EDEEC outperformed previous approaches among homogeneous (LEACH, TEEN, HEED, PEGASIS) & heterogeneous (SEP, DEEC, DDEEC) algorithms by constructing minimum energy consuming routing for each round of communication. Minimizing the total energy of system by distributing the load equally to the node has a great impact on Wireless Sensor Network lifetime.

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