Clustering Algorithms for Reducing Energy Consumption - A Review

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Abstract

Energy awareness is an essential design flaw in wireless sensor network. Clustering is the most highly regarded energy-efficient technique that offers various benefits such as energy efficiency and network lifetime. Clusters create hierarchical WSNs that introduce the efficient use of limited sensor node resources and thus enhance the life of the network. The goal of this paper is to provide an analysis of the various energy efficient clustering algorithms. Analysis is based on the energy efficiency and network lifetime. This review paper provides an analysis of different energy-efficient clustering algorithms for WSNs.

Key words:

WSN, clustering algorithms, LEACH, p-LEACH, Cluster head.

1. Introduction

Small Wireless Sensor Networks Computing resources which may be of fundamental importance Restrict your lifespan on the network. This is an ensemble of Computing nodes, each with sensing equipment Devices, and transceivers for internet. Those nodes of feeling Form an adhoc network to be used in a variety of ways Goal Detection and Monitoring software, Health inspections[1]. Recent technical earlier in “micro-electro-mechanical systems (MEMS)”, wireless networking and mobile equipment’s have made it possible to manufacture minimum-cost, minimum-power, multipurpose sensor nodes that are limited in size and communicate unconstrained at short wavelengths[2]. “Clustering is a mechanism for arranging nodes into logically isolated entities in a network called clusters. Clustering will simplify such essential functions as routing, assigning data rates and controlling channels”[3].The sensor module used in “wireless sensor networks” are highly “power-constrained”, so improving the duration of the whole network is considered mostly in design.

An energy intensive method for the clustering with appropriate parameters is designed to minimum usage of power and increase the operation life of the system [4]. This has proposed a range of clustering methods in different contexts In fact, several of those algorithms are heuristic and aim to-energy usage [5].The method of communicating or transmitting messages must be structured to maintain the sensors' sufficient energy resources. Clustering sensors into clusters, since Sensors can relay data just to cluster heads and then transmit the information to data center, will save resources. In recent years, several algorithms have based primarily on the nodes' energy balance to extend their lifespan. “LEACH” algorithm, plays a major role in minimizing node power usage and optimizing the lifespan of the network [6]. Advancement in LEACH like LEACH-C and pLEACH lead to prolonging the lifespan of WSN networks. In this paper we discussed LEACH, HEED, One hop distance and clustering angle, LEACH-C, PLEACH, EEUC and REAC-IN clustering algorithms that helps in reducing energy consumption.

2. Literature review

Clustering approaches for WSNs will typically be classified on the basis of an overall structural and operational network and the intent of the “node” group approach including the

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necessary number and things of the clusters created[7]. Several theoretical studies have been proposed for coping with energy depletion issues with nodes. In WSNs, we urgently need to conserve and reduce the electricity usage. HeinZelman suggested a clustering method called LEACH and LEACH-C to address these problems. The energy usage can be reduced and regulated with all approaches to extend the network's lifespan. However, the variance of band numbers and the unequal sharing of cluster heads hinder the benefits of clustering algorithms[8]. There have been many revisions to the "LEACH" protocol such as "TL-LEACH", "E-LEACH", "M-LEACH"[9], "LEACH-C", "V-LEACH", "W-LEACH", "T-LEACH"[10]. The new "routing algorithm" is contrasted to earlier algorithms, e.g., "LEACH" , "LEACH-C". modeling tests reveal, new "routing algorithm" has increased "WSN" efficiency by at least 65%, decreases WSN energy usage by up to 62%, and increases the positively transmitted pack part by at least 56% relative to earlier routing algorithms. "I-LEACH" is an effective algorithm which considers the problems of substantially reducing energy consumption[11].

The "optimum one-hop distance and clustering angle" was discovered by rising the usage of power among the "inter-cluster" and the "intra-cluster". Simulation tests show that the "clustering algorithm" will efficiently minimize energy usage and improve the lifespan of the device[4].

When cluster heads function together to move their facts to "base station", band heads close base place become overwhelmed by heavy transmit traffic, led to expire early, leave network zones exposed and causing system partition. An "Energy Efficient Unequal Clustering (EEUC)" method has been suggested to solve the issue. The "nodes" are shared into varying size clusters, as well as the clusters nearest to the base place have small dimensions than one who is farther from the sink node. Thereby "cluster heads" near to sink node could save various resources between clusters for data sending. We are also proposing an "energy-aware multi-hop routing protocol" for the statement between clusters. Effects of the simulation indicate that our uneven clustering process manages consumed energy well across all nodes and significantly increase the lifespan of the network[12].

Several protocol are built on clusters of the same size and even use clusters of the same scale. And can use rotational methods to limit the number of cluster head choices. Multiple simulation settings are used as particular approaches are used for clustering. On "HEED-based clustering protocols" which are "HEED", "UHEED", "RUHEED" , "R-HEED" which is "ER-HEED" a comparative review was conducted. The same network model has been found, the same energy consumption model and calculated protocol lifespan by looking at specific case studies. The analysis of contrast indicates that the choosing of the procedure To be included according to the case study and the calculation of lifespan of the "WSN" considered. "Hybrid, Energy-Efficient, Distributed (HEED)" is a similarly clustering strategy of comparable size that generates "clusters" of the same scale. The collection of CHs in "HEED" is focused on sensor node remaining power and is among the variables: node point or range between the neighboring nodes and the CH. The creation of HEED clusters takes place in three phases: initialization; iteration and finalization[13]. HEED has four primary objectives. (i) expanding the lifespan of the link by spreading drive consumption; (ii) stopping the clustering cycle with a constant amount of reiterations; (iii) reducing above power; and (iv) generating accurately dispersed "cluster heads". Our approach to clustering requires no conclusions regarding node propagation, or node capacities, e.g. location-awareness[14].

Another protocol, named the "Regional Energy Aware Clustering with Isolated Nodes (REAC-IN)", that suggests a new "regional energy aware clustering approach" by "isolated nodes" for "WSNs". CHs are picked at "REAC-

IN" founded on weight. Weight is measured to make to the lasting strength of each sensor. Wrongly designed global "clustering algorithms" can allow nodes to split from CHs. These "isolated nodes" link with the drain through use to excess electricity. The state median energy and the length in between the sensing devices as well as the drain are being used to decide whether either the "isolated node" has sent it's own data to a "CH" node in the following round, or sink to prolong lifetime of network. The new study found that "REAC-IN" outperforms other protocols of "clustering".[15]

An advanced "LEACH (LEACH-C)" protocol called "partition-based LEACH (pLEACH)", which first divides the system into optimum amount of sectors, so select the node as a lead for every segment which has highest, using the integrated calculations.

The result obtained and study indicate, "pLEACH" may attain far stronger WSN efficiency in terms of power dispersion and lifespan of the network[8].

3. Energy efficient clustering protocols:

3.1 LEACH:

Heinzelman proposed an algorithm for clustering, called LEACH. Essential clustering protocol strategies for "WSNs" is the "LEACH Low-Energy Adaptive Clustering Hierarchy".

Probabilistically the LEACH "cluster-heads" are picked. when we look at one round of LEACH, it is clear that for a specified group of nodes, a stochastic cluster-head selection does not necessarily result in minimal energy consumption during the data transfer. Both cluster heads can be placed along network edges, or neighboring nodes may become "cluster heads". during this situation, many nodes must be traverse large lengths to meet a "cluster-head". Taking a look to 2 or three spins, however, we concluded that only a set of desirable sensor nodes outcomes in an undesirable afterward round collection of sensor nodes because LEACH attempts to spread energy use across all nodes[16].

Energy consumption model for LEACH:

The energy consumption ratings have been established in order to evaluate energy consumption ratings:

where N = total set of nodes for a network,

K = amount of cluster heads,

lc = duration of the control note.

(A) Each cluster header transmits a response to each node in the network following the cluster header election.

$$E1^{LEACH} = K * E_{NCH} + (N-K) * l_c \quad E_{elec}$$

(B) After the warning has been issued, each node must pick the nearest "cluster head" to reach the network.

$$E2^{LEACH} = (N-K) * l_c \quad E_{elec} + (N-K) * \quad E_{NCH}$$

(C) Will the head of the cluster transmit a TDMA message to every participant nodes in its group

$$E3^{LEACH} = K * E_{NCH} + (N-K) * l_c \quad E_{elec}$$

(D)Secure routing:

$$E4^{LEACH} = K * E_{NCH} + (N-K) * E_{elec}$$

Net energy expended is:

$$E1^{LEACH} + E2^{LEACH} + E3^{LEACH} + E4^{LEACH}$$

3.2 LEACH-C

The method is centralized. Cluster heads are picked from sink node. The subsequent actions are identical to those taken at LEACH. Consideration is given to residual energy, and using annealing algorithm a better cluster is created. Yet it still has several pitfalls, apart from the LEACH issues it takes a long time to use the annealing method to create energy-saving clusters. In addition, in “LEACH-C”, each node will record its residual energy at the initialization of each round, resulting in a significant extra energy consumption.

Energy is processed at LEACH-C in the following 3 rounds:

(A) After every round of cluster creation each node records its power usage to sink node.

$$E1^{LEACH-C} = N * (l_c \; E_{elec} + l_c \; \mathcal{E}_{amp} \, d^m$$

(B)The sink node transmits notification to all nodes after a session of cluster head election

$$E2^{LEACH-C} = N * l_c \; E_{elec}$$

(C)Secure routing

$$E3^{LEACH-C} = K * E_{CH} + (N - K) * E_{NCH}$$

By adding above 3 energy fromulas total energy is:

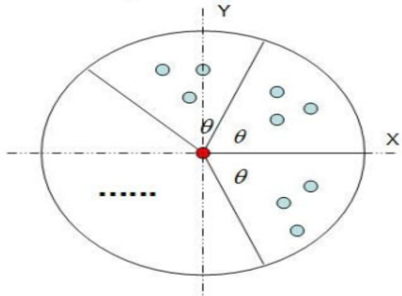
$$E1^{LEACH-C} + E2^{LEACH-C} + E3^{LEACH-C}$$

3.3 pLEACH:

At pLEACH the whole section of the system is partitioned into different sectors. For any sector, a “head node” is chosen to collect details from those within the sub-area, and then forward this to base station. Like the preceding clustering process, our approach will evenly spread cluster heads throughout the entire system, thereby reducing the resource cost of data transmission, increasing network life and ensuring high quality communication. The algorithm pLEACH is composed of 2 rounds:

(A)The base station calculates the optimum amount of node ends and splits the whole network into sub areas appropriately within a given system.

(B) The base station selects one entity as the head of the cluster with full residual energy in sub area. The base station ultimately transmits the allocated headers to the entire system, and all participant nodes enter their nearest cluster heads before obtaining the transmitted address[8].



Power is absorbed in 3 rounds:

(a) Initialization: both clusters must send notification to the base station and have a answer from base station, and only often for multiple cycles of communication, for that this power usage may be prevented.

(b) Base station transmits a notification to all nodes after each “Cluster Head Election”.

$$E1^{pLEACH} = N * l_c \; E_{elec}$$

(c) Secure routing.

$$E2^{pLEACH} = K * E_{CH} + (N - K) * E_{NCH}$$

Net power absorbed:

$$E1^{pLEACH} + E2^{pLEACH}$$

pLEACH<LEACH-C < LEACH

3.4 “one hop distance and clustering angle”:

At LEACH, it is challenging to control the exact scale of the clusters and maximize the device's lifetime by controlling Cluster Distribution. However, if the algorithm tries to suit each node's energy consumption, the cluster heads are dynamically chosen and it often results in increased usage of energy for the cluster head set-up. At the same time, due to repeated reception of the new cluster leader's broadcast message, any remaining resources of general nodes can not be used efficiently, the energy balance for all nodes is difficult to realize A new protocol is provided due to the above issues, which is implemented to increase the lifespan of the system by redusing the power usage for “inter-cluster and intra-cluster” contact.

All modules are clustered into fixed groups to ensure optimal parameters. The clusters sizes that are nearest to sink node are smaller than those that are farther from the BS. The various cluster sizes suggest that the "cluster heads" closest to the "BS" have ample capacity to relay merged results from certain cluster heads more distant from the BS, that describes balance of power utilization in the “inter-cluster”. A traditional “intra-cluster” structure in which the initial “cluster head” is constantly adjusted as the local control core to the number of cluster changes and power usage for new “cluster head” architecture. The energy demand for coordination between the “inter-cluster” and the “intra-cluster” is lowered with the “clustering protocol”.

“Model energy consumption”

In WSN, the active node 's principal energy consumption consists of 3 phases:
send messages, receive messages and process the data. The condensed model for increasing part of energy usage can be described as

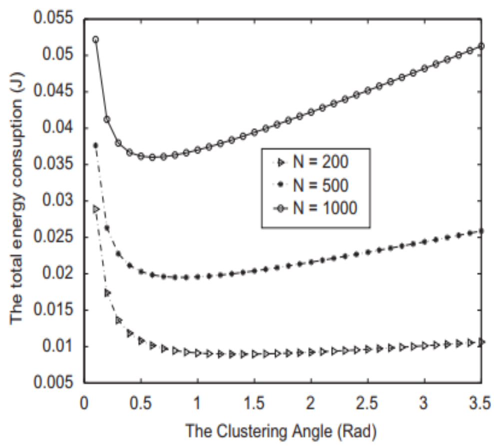
$$PT(k) = Eelec \times k + Eamp \times d \times k$$
$$PR(k) = Eelec \times k$$
$$Pcpu(k) = Ecpu \times k$$
Eq(1)

Where k is packet length (bits), d is transfer length (m). To run the radio circuitry the radio disperse Eelec (nJ/bit) per bit. Light (nJ/bit/m2) is the following capacity
Elections provided by the sender at the receiver's demodulator for an appropriate Eb/N0. Ecpu (nJ/1) is the dispersion of power to be stored per second.
Based on Eq(1), The power usage for the modules obtaining and sending k bits from the “cluster head” can be described as:

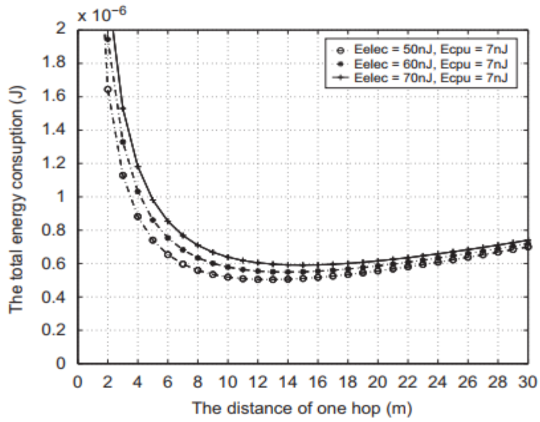
$$P = PT(k) + Pcpu(k) + PR(k) = k(2Eelec + Ecpu + Eamp \times d)$$
Eq(2)

In Eq. (2), The electricity usage correlates similarly to the duration of the data packets or notification packets. If it is possible to reduce the message packets the electricity usage can be reduced. Around the same time the supply of electricity is

If the propagation interval is smaller than the maximum, in strict relation to d2. Then the volume of energy expended is in strict relation to d4.



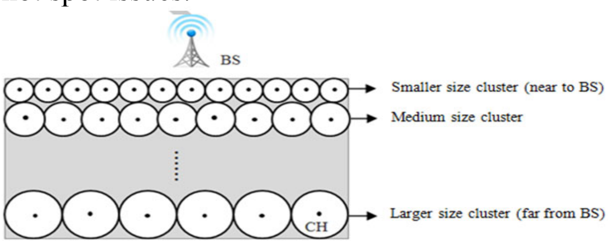
The relationship between “energy consumption” and “clustering angle.



The relationship between “one hop distance” and energy consumption[4].

3.5 EEUC

Various clustering and unequal clustering methods are proposed for such an energy-efficient WSN. whereas many detailed clustering method datasets were published, relatively one has performed a survey on unequal clustering techniques. It reviews probabilistic unfair clustering protocols and protocols are contrasted with node deployment area, versatility, position responsiveness and files Assembly. Another analysis will be provided of the unequal clustering approaches focused on random processes. This contrasts various protocols based upon the number of nodes, energy consumption, balanced cluster, position sensitivity and degree of diversity. The purposes of clustering unevenly are the same as clustering equals for certain extra features. The links are grouped in WSN dependent on program criteria, with specific goals. The most prominent areas of unequal clustering are preservation and Energy reducing hot spot issues.

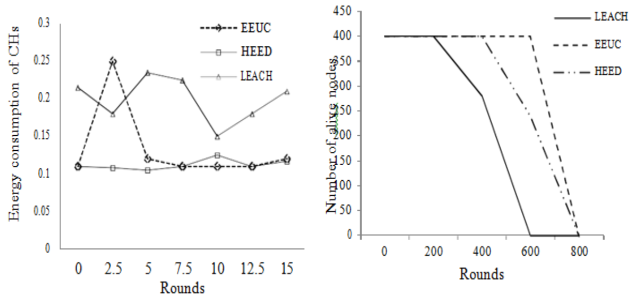


If cluster heads eventually move their information to the BS, the cluster points near to the BS are overwhelmed by intense transmission congestion and begin to die soon, rendering network exposed and triggering system partitioning. To fix this issue, we suggest "Energy Efficient Unequal Clustering (EEUC)" method for collecting periodic data in "WSN". The clusters are partitioned into groups of different scale, and clusters nearest to the base station have fewer parts than farther to access point. "Cluster heads" near to the sink node will maintain some resources for sending data between clusters. Modeling of algorithm suggest that our uneven clustering mechanism handles power usage well over all networks and greatly boosts network life.

Compared to HEED and LEACH, EEUC's energy use and network lifetime Firstly, it contrasts the sum of energy expended in three algorithms by cluster hands. 15 Simulations of live rounds are tested and the cumulative amount of energy expended on both cluster heads is seen below. The Strength in EEUC cluster heads absorbed per round are significantly smaller than in LEACH and those around the similar as in EEUC always. Since cluster heads conduct their packs directly to the base station at LEACH energy practice is considerable superior. In "EEUC" and "HEED" cluster heads spread their facts through multi-hop to the sink node, hence a substantial amount of save energy. First, by analyzing the lifetime of the system, the energy performance of three algorithms is assessed[17].

(a) Energy consumption of HEED, LEACH and EEUC

(b) Network period of HEED, LEACH and EEUC



3.6 HEED

Several protocol are built on clusters of the same size and even use clusters of the same scale. And can use rotational methods to limit the number of cluster head choices. Multiple simulation settings are used as particular approaches are used for clustering. On "HEED-based clustering protocols" which stay "HEED", "UHEED", "RUHEED" and an original variant of "R-HEED" which stays "ER-HEED" a comparative review was conducted. The same network model has been found, the same energy consumption model and calculated protocol lifespan by looking at specific case studies. The analysis of contrast indicates that the choosing of the procedure to be included according to the

case study and the calculation of lifespan of the "WSN" considered. "Hybrid, Energy-Efficient, Distributed (HEED)" is a similarly sized assembling technique that generates bands of the same scale. The collection of CHs "HEED" is founded on sensor node remaining energy also is one of the subsequent variables: nodule point or space between the neighboring nodes and CH.
The initialization process assigns the likelihood to each node to become provisional leader of the cluster

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

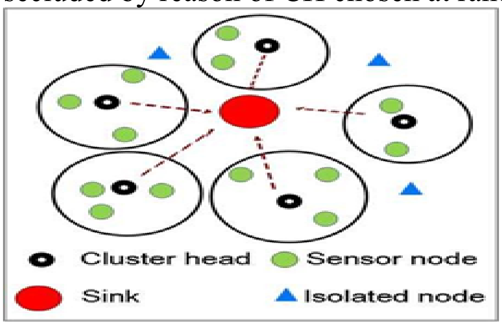
Whereas Cprob is the actual possibility (i.e., a predefined value), energy level is Eresidual and the maximal output of the sensor nodes is Emax[13].
Creation of HEED clusters takes place in three stages:
Initialize; Iteration (Handling) and Finalize.

```
I. Initialize
1. S_nbr ← {v: v lies within my cluster range}
2. Compute and broadcast cost to ∈ S_nbr
3. CH_prob ← max(C_prob × E_residual/E_max , p_min)
4. is_final CH ← FALSE

II. Main Processing
Repeat
1.  If ((S_CH ← {v: v is a cluster head})≠ ϕ)
2.     my_cluster_head ← least_cost(S_CH)
3.     If (my_cluster_head = NodeID)
4.       If (CH_prob = 1)
5.         Cluster_head_msg(NodeID,final CH,cost)
6.         is_final CH ← TRUE
7.       Else
8.         Cluster_head_msg(NodeID, tentative_CH,cost)
9.  ElseIf (CH_prob = 1)
10.    Cluster_head_msg(NodeID,final CH,cost)
11.    is_final CH ← TRUE
12. ElseIf Random(0,1) ≤ CH_prob
13.    Cluster_head_msg(NodeID,tentative_CH,cost)
14. CH_previous ← CH_prob
15. CH_prob ← min(CH_prob × 2, 1)
Until CH_previous = 1

III. Finalize
1. If (is_final CH = FALSE)
2.    If ((S_CH ← {v: v is a final cluster head}) ≠ ϕ)
3.       my_cluster_head ← least_cost(S_CH)
4.       join_cluster(cluster_head_ID, NodeID)
5.    Else Cluster_head_msg(NodeID, final CH, cost)
6. Else Cluster_head_msg(NodeID, final CH, cost)
```

HEED has four primary objectives. (i) expanding the lifespan of the link by spreading drive consumption; (ii) stopping the clustering cycle with a constant amount of reiterations; (iii) reducing above power (toward be exponential in the aggregate of nodes) and (iv) generating Well distributed Heads of Cluster. Our approach to clustering requires no conclusions regarding node propagation, or node capacities, e.g. location-awareness[14].

3.7 REAC IN

Another protocol, named the "Regional Energy Aware Clustering with Isolated Nodes (REAC-IN)", that suggests a different "regional energy aware clustering approach" through "isolated nodes" used for WSNs. Cluster heads are picked at "REAC-IN" founded on weightiness. Weight is designed rendering to every device's enduring energy besides the global mean both sensors from each cluster have energy. Inadequately crafted spread "clustering algorithms" will lead nodes toward separate themselves from cluster heads. Such inaccessible nodes connect to excess power by usage with the drain. The national ordinary energy and space among the devices and the sink be present to decide if, in following round, either the "isolated node" transmit its facts to a "CH" node, or sink toward prolong network lifetime. Latest findings of research simulation showed that "REAC-IN" outperforms more "Clustering" Algorithm. Now a distributed WSN made by inadequately planned Clustering procedures, nodes can be secluded by reason of CH chosen at random.



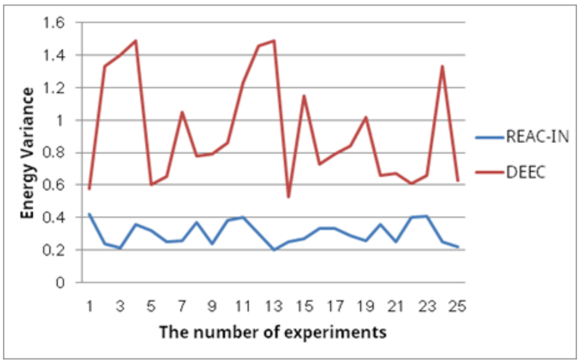
REAC-IN protocol assigns **p**, dependent on the Enduring energy also total spatial activity of all the sensors to extend network existence in rising cluster. Average regional energy of node **ni** the figure of nodes in its collection **c** at round $\mathbf{r-1}$ is nc the enduring energy of node ni is in the cluster, and $\mathbf{E_i(r)}$. The national average energy $\mathbf{E_{c,i}(r-1)}$is well-defined as

$$E_{c,t}(r-1) = \frac{\sum_{i=1}^{n_c} E_i(r)}{n_c}$$

$$p_i = p\frac{E_i(r)}{E_{c,t}(r-1)}$$

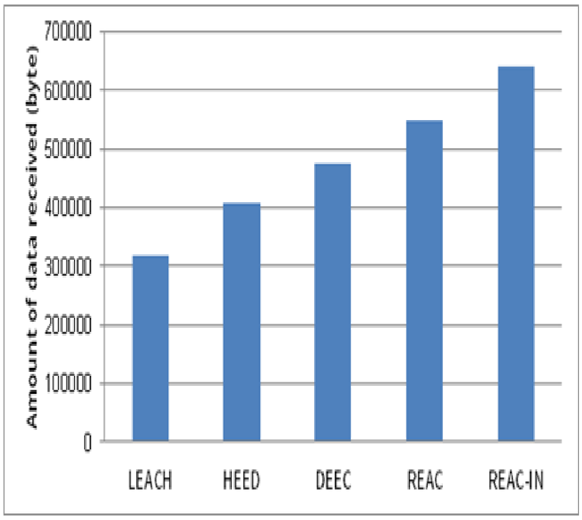
We compared REAC-IN with the classic distributing clustering procedures DEEC, LEACH and HEED Use efficiency measures including amount of data obtained at just the sink and standard life span.

1. Comparison with variation in the distribution of enduring energy generated through DEEC system and REAC-IN system. Dissimilarity in the energy rates of both nodules is main indicator of enduring energy for resident or worldwide normal energy in REAC- IN and DEEC. A large change means that the total regular energy of network can not adequately reflect the condition of the whole network.
2.



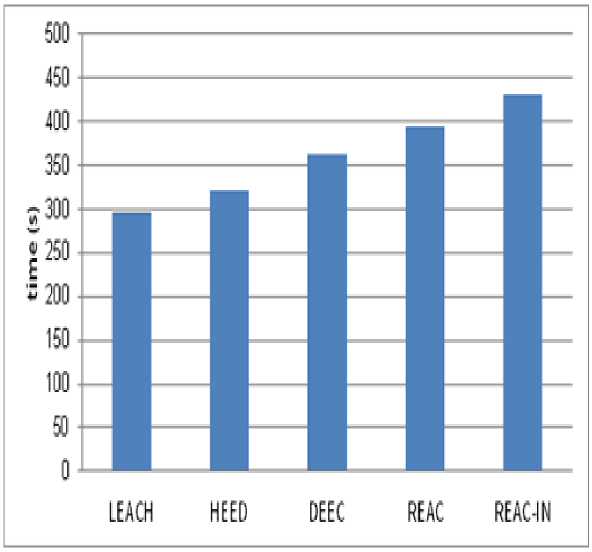
Varianc of energy level

3. In the REAC- IN protocol the volume of data obtained at the sink was larger than the HEED,DEEC and LEACH procedures. The outcome shows in REAC-IN will assistance relay facts across the entire network from nodes to sink.



Numeral of data rceived at sink

4. Lifetime total of 50 imitations. It demonstrate that REAC-IN in making a important improvement in lifetime. The lifespan of the network in REAC-IN is greater than other protocols, which will increase the lifetime of the network by up to 40 per cent. In fact, the issue with the isolated node is fixed so that it can extend the whole lifespan of the network[15].



Average lifetime of 50 simulations

5. Analysis of clustering algorithms:

Year	Author name	Name of protocol	Location awareness	Load balancing	Energy efficient	Average variance of residual energy at each round
2000	heinzelman	LEACH	Not required	Medium	Poor	0.1301
2002	Heinzelman,et.al	LEACH-C	Not required	Medium	Medium	0.1261
2004	Youns n fahmny	HEED	Not required	Medium	Medium	0.1
2005	Chengfa Li, Mao Ye, Guihai Chen	EEUC	Not required	Good	High	0.25
2008	Zhang yang, xiang min	One hop distance	Required	Good	Medium	0.5
2010	Haosong Gou and Younghwan Yoo	pLEACH	Required	Very good	Very high	0.1196
2013	Tung hung chiang, jeng sheou leu,	REAC-IN	Required	Very good	High	0.4

6. Conclusion:

After explaining and studying different clustering algorithms that reduce energy consumption we can say that routing protocols are just not enough in today's era therefore the need for clustering algorithms felt. We have discussed LEACH, LEACH-C, P-LEACH, HEED, EEUC, ONE HOP DISTANCE, and REAC-IN clustering algorithms and we concluded after analyzing these that, all algorithms save energy resources but P-LEACH consume less energy as compare to other algorithms and increase the lifetime of network.

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