# EXTENDING NETWORK LIFETIME IN WIRELESS SENSOR NETWORK USING INTEGRATED AND HYBRID STRATEGY

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**Abstract**

**Sensors at heavy traffic locations quickly deplete their energy resources and die much earlier, leaving behind energy hole and network partition. In this paper, an integrated and efficient clustering concept for large scale wireless sensor network, the Integrated Distributed Clustering Algorithm (IDCA) is proposed based on three concepts. First, the aggregated data is forwarded from cluster head to the base station through cluster head of the next higher layer with shortest distance between the cluster heads. Second, cluster head is elected based on the clustering factor, which is the combination of residual energy and the number of neighbors of a particular node within a cluster. Third, each cluster has a crisis hindrance node, which does the function of cluster head when the cluster head fails to carry out its work in some critical conditions. The key aim of the proposed algorithm is to accomplish energy efficiency and to prolong the network lifetime. The proposed distributed clustering algorithm is contrasted with the existing clustering algorithms LEACH and HEED. The proposed clustering algorithm shows betterment in Network stability, Network lifetime, Packet delivery ratio and Link reliability.**

**Keywords: Wireless sensor network (WSN), distributed clustering algorithm, cluster head, residual energy, energy efficiency, network lifetime.**

## 1. INTRODUCTION

Wireless sensor network (WSN) is a collection of huge number of small, low-power and low-cost electronic devices called sensor nodes. Each sensor node consists of four major blocks: sensing, processing, power and communication unit and they are responsible for sensing, processing and wireless communications (figure 1).

These nodes bring together the relevant data from the environment and then transfer the gathered data to base station (BS). Since WSNs has many advantages like self-organization, infrastructure-free, fault-tolerance and locality, they have a wide variety of potential applications like border security and surveillance, environmental monitoring and forecasting, wildlife animal protection and home automation, disaster management and control.

Considering that sensor nodes are usually deployed in remote locations, it is impossible to recharge their batteries. Therefore, ways to utilize the limited energy resource wisely to extend the lifetime of sensor networks is a very demanding research issue for these sensor networks.

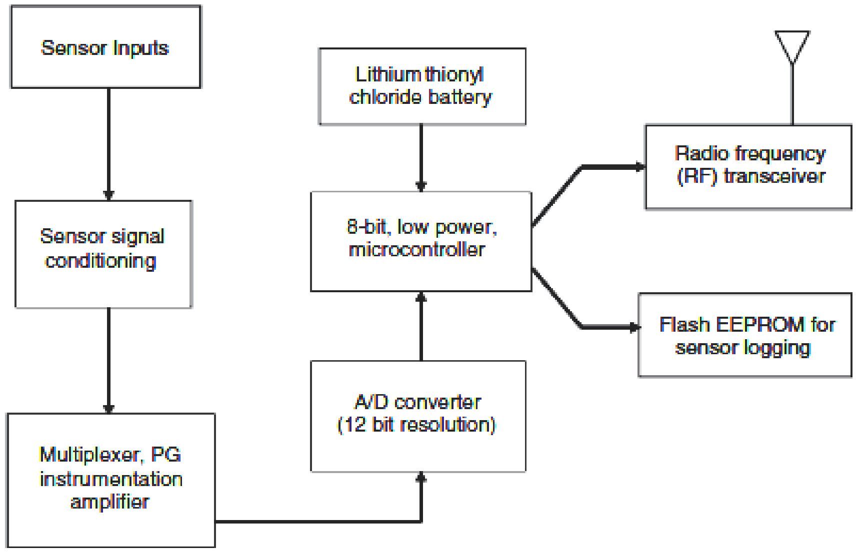


Figure 1: Functional block diagram of a wireless sensor node

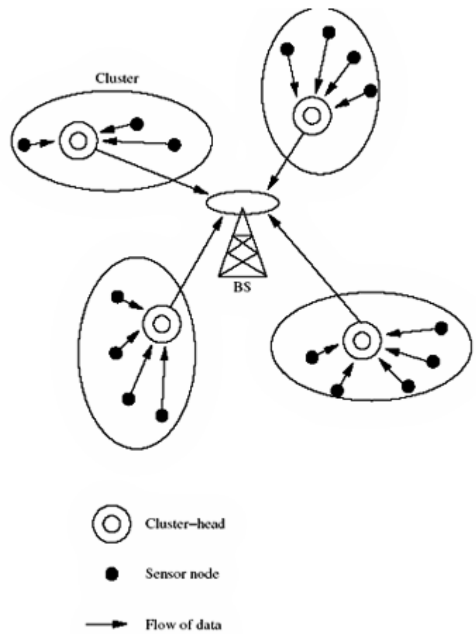


Figure 2: Cluster formation in a wireless sensor network

Clustering [2-7] is an effectual topology control approach, which can prolong the lifetime and increase scalability for these sensor networks. The popular criterion for clustering technique (figure 2) is to select a cluster head (CH) with more residual energy and to spin them periodically. The basic idea of clustering algorithms is to use the data aggregation [8-11] mechanism in the cluster head to lessen the amount of data transmission. Clustering goes behind some advantages like network scalability, localizing route setup, uses communication bandwidth [17] efficiently and takes advantage of network lifetime [12-16]. By the data aggregation process, unnecessary communication between sensor nodes, cluster head and the base station is evaded. In this paper, a well-defined model of distributed layer-based clustering algorithm is proposed based of three concepts: the aggregated data is forwarded from the cluster head to the base station through cluster head of the next higher layer with shortest distance between the cluster heads, cluster head is elected based on the clustering factor and the crisis hindrance node does the function of cluster head when the cluster head fails to carry out its work. The prime aim of the proposed algorithm is to attain energy efficiency and increased network lifetime.

## 2. A REVIEW OF EXISTING CLUSTERING ALGORITHMS

Bandyopadhyay and Coyle anticipated EEHC [18], which is a randomized clustering algorithm which categorizes the sensor nodes into hierarchy of clusters with an objective of minimizing the total energy spent in the system to communicate the information gathered by the sensors to the information processing center. It has variable cluster count, the immobile cluster head aggregates and relays the data to the BS. It is valid for extensive large scale networks. The peculiar negative aspect of this algorithm is that, some nodes remain un-clustered throughout the clustering process.

Barker, Ephremides and Flynn proposed LCA [19], which is chiefly developed to avoid the communication collisions among the nodes by using a TDMA time-slot. It makes utilization of single-hop scheme thereby attaining high degree of connectivity when CH is selected randomly. The restructured version of LCA, the LCA2 was implemented to lessen the number of nodes compared to the original LCA algorithm. The key drawback of this algorithm is that, the single-hop clustering leads to the creation of more number of clusters.

Nagpal and Coore proposed CLUBS [20], which is executed with an idea to form overlapping clusters with maximum cluster diameter of two hops. The clusters are created by local broadcasting and its convergence depends on the local density of the wireless sensor nodes. This algorithm can be implemented in asynchronous environment without dropping efficiency. The main difficulty is the overlapping of clusters, clusters having their CHs within one hop range of each other, thereby both the clusters will collapse and CH election process will get restarted.

Demirbas, Arora and Mittal brought out FLOC [21], which shows double-band nature of wireless radio-model for communication. The nodes can commune reliably with the nodes in the inner-band and unreliably with the nodes that are in the outer-band. The chief disadvantage of the algorithm is, the communication between the nodes in the outer band is unreliable and the messages have maximum probability of getting lost during communication.

Ye, Li, Chen and Wu proposed EECS [22], which is based on a supposition that all CHs can communicate directly with the BS. The clusters have variable size, those closer to the CH are larger in size and those farther from CH are smaller in size. It is really energy efficient in intra-cluster communication and shows an excellent improvement in network lifetime. EEUC is anticipated for uniform energy consumption within the sensor network. It forms dissimilar clusters, with a guessing that each cluster can have variable sizes. Probabilistic selection of CH is the focal shortcoming of this algorithm. Few nodes will be gone without being part of any cluster.

Yu, Li and Levy proposed DECA, which selects CH based on residual energy, connectivity and a node identifier. It is greatly energy efficient, as it uses lesser messages for CH selection. The main trouble with this algorithm is that high risk of wrong CH selection which leads to the discarding of every packets sent by the wireless sensor node.

Ding, Holliday and Celik proposed DWEHC, which elects CH on the basis of weight, a combination of nodes' residual energy and its distance to the neighboring nodes. It produces well balanced clusters, independent of network topology. A node possessing largest weight in a cluster is designated as CH. The algorithm constructs multilevel clusters and the nodes in every cluster reach CH by relaying through other intermediate nodes. The foremost problem occurs due to much energy utilization by several iterations until the nodes settle in most energy efficient topology.

Younis and Fahmy proposed Hybrid Energy-Efficient Distributed Clustering (HEED), which is a distributed algorithm which selects the CH based on both residual energy and communication cost. Basically HEED was proposed to avoid the random selection of CHs. Though LEACH protocol is much more energy efficient when compared with other clustering algorithms, the main drawback in LEACH is the random selection of CH. In the worst case, the

CH nodes may not be evenly distributed among the nodes and it will have its effect on data gathering. HEED protocol gets executed in three subsequent phases: initialization phase, repetition phase and finalization phase. Initialization phase is the stage in which the initial percentage of cluster head will be given to the nodes. Repetition phase is the phase in which until the CH node was found with least transmission cost, the iteration happens. If the node cannot find the appropriate CH, then the concerned node itself will be selected as CH. Finalization phase is the stage in which the selection of CH will be finalized.

The initial stage of Threshold sensitive Energy Efficient Network (TEEN) protocol is the formation of clusters. In this mechanism, every cluster member nodes becomes a cluster head for a particular time interval referred as cluster period as formulated by Manjeshwar and Agarwal. TEEN protocol has been developed for reactive networks so as to take action for abrupt changes in the sensed attributes. TEEN is appropriate for time critical applications, but not suitable for applications where periodic reports are required.

The main idea in Power-Efficient Gathering in Sensor Information Systems (PEGASIS) protocol is for node to receive from and transmit to close neighbors and take turns for being the leader for transmission of data to BS as formulated by Stephanie Lindsey and Cauligi Raghavendra. This approach distributes the energy load evenly among the sensor nodes. The nodes randomly placed in the field, organize themselves in the form of chain using greedy algorithm. Alternatively, BS computes this chain and broadcasts it to all the nodes. For data gathering, each node receives the data from one neighbor, fuses its own data and transmits it to the next node in the chain. In a given round, a simple token passing approach is initiated by the leader to start the data transmission from the ends of the chain. Here the cost is very less because the size of the token is very small. Thus in PEGASIS, each node receives and transmits one packet in each round and be the leader at least once in n rounds (n are no of nodes). PEGASIS protocol has its major applications in environment monitoring. The nodes sense various environmental factors such as temperature, humidity, pressure, etc. Each node fuses its sensed data with the adjacent node. The CH finally has all the sensed data, which it then sends to the base station. PEGASIS protocol has its main application in characterizing and monitoring the quality of environment.

## 3. AN EVALUATION OF LEACH ALGORITHM

LEACH [1] is one of the most well-liked clustering mechanisms for WSNs and it is considered as the representative energy efficient protocol. In this protocol, sensor nodes are unified together to form a cluster. In each cluster, one sensor node is chosen arbitrarily to act as a cluster head (CH), which collects data from its member nodes, aggregates them and then forwards to the base station. It disperses the operation unit into many rounds and each round consists of two phases: the set-up phase and the steady phase. During the set-up phase, initial clusters are fashioned and cluster heads are selected. All the wireless sensor nodes produce a random number between 0 and 1. If the number is lesser than the threshold, then the node selects itself as the cluster head for the present round. The threshold for cluster head selection in LEACH for a particular round is given in equation 1. Gone selecting itself as a CH, the sensor node broadcasts an advertisement message which has its own ID. The non-cluster head nodes can formulate an assessment, which cluster to join based on the strength of the received advertisement signal. After the decision is made, every non-cluster head node should transmit a join- request message to the chosen cluster head to specify that it will be a member of the cluster. The cluster head fashions and broadcasts a time division multiple access (TDMA) schedule to exchange the data with non-cluster sensor nodes without collision after it receives all the join-request messages.

$$T(n) = \begin{cases} \dfrac{p}{1 - p * (r \bmod 1/p)} & if \; n \in G \\ 0 & otherwise \end{cases} \tag{1}$$

Where p is the preferred percentage of cluster heads, r is the current round number and G is the set of nodes which have not been chosen as cluster head for the last 1/p rounds.

The steady phase commences after the clusters are fashioned and the TDMA schedules are broadcasted. All of the sensor nodes transmits their data to the cluster head once per round during their allotted transmission slot based on the TDMA schedule and in other time, they turn off the radio in order to trim down the energy consumption. However, the cluster heads must stay awake all the time. Therefore, it can receive every data from the nodes within their own clusters.

On receiving the data from the cluster, the cluster head carries out data aggregation mechanism and onwards it to the base station directly. This is the entire mechanism of the steady state phase. After a certain predefined time, the network will step into the next round. LEACH is the basic clustering protocol which processes cluster approach and it can prolong the network lifetime in comparison with other multi-hop routing and static routing. However, there are still some hiding problems that should be considered.

LEACH does not take into account the residual energy to elect cluster heads and to construct the clusters. As a result, nodes with lesser energy may be elected as cluster heads and then die much earlier. Moreover, since a node selects itself as a cluster head only according to the value of the calculated probability, it is hard to guarantee the number of cluster heads and their distribution. Also in LEACH clustering algorithm, the cluster heads are selected randomly and hence the weaker nodes drain easily.

To rise above these shortcomings in LEACH, a model of distributed layer-based clustering algorithm is proposed, where clusters are arranged in to hierarchical layers. Instead of cluster heads directly sending the aggregated data to the base station, sends them to their next layer nearer cluster heads. These cluster heads send their data along with that received from lower level cluster heads to the next layer nearer cluster heads. The cumulative process gets repeated and finally the data from all the layers reach the base station. The proposed model is dedicated with some expensive designs, focusing on reduced energy utilization and improved network lifetime of the sensor network.

## 4. THE PROPOSED CLUSTERING ALGORITHM

The proposed clustering algorithm, the Integrated Distributed Clustering Algorithm (IDCA) is well distributed, where the sensor nodes are deployed randomly to sense the target environment. The nodes are divided into clusters with each cluster having a CH. The nodes throw the information during their TDMA timeslot to their respective CH which fuses the data to avoid redundant information by the process of data aggregation. The aggregated data is forwarded to the BS. Compared to the existing algorithms, the proposed algorithm has three distinguishing features. First, the aggregated data is forwarded from the cluster head to the base station through cluster head of the next higher layer with shortest distance between the cluster heads. Second, cluster head is elected based on the clustering factor, which is the combination of residual energy and the number of neighbors of a particular node within a cluster. Third, each cluster has a crisis hindrance node, which does the function of cluster head when the cluster head fails to carry out its work in some conditions.

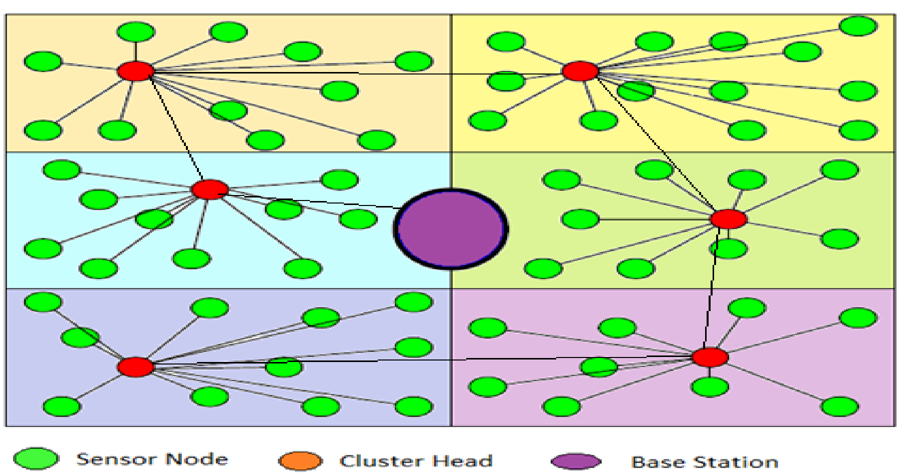


Figure 3: Aggregated data forwarding in the proposed algorithm

A. *Aggregated Data Forwarding*

In a network of N nodes, each node is assigned with an exclusive Node Identity (NID). The NID just serves as a recognition of the nodes and has no relationship with location or clustering. The CH will be placed at the center and the nodes will be organized in to several layers around the CH. Every clusters are arranged into hierarchical layers and layer numbers are assigned to each clusters. The cluster that is far away from the base station is designated as the lowest layer and the cluster nearer to the base station is designated as the highest layer.

The main characteristic feature of the proposed algorithm is that the lowest layer cluster head forwards only its own aggregated data to the next layer cluster head but the highest layer forwards all the aggregated data from the preceding cluster heads to the base station (figure 3). Thus lower workload is assigned to the lower layers but the higher layers is assigned with greater workload. The workload assigned to a particular cluster head is directly proportional to the energy utilization of the cluster head.

In order to balance the energy utilization among the cluster head, the concept of variable transmission power is employed, where the transmission power reduces with increase in layer numbers. In LEACH, each cluster head forwards the aggregated data to the base station directly which uses much energy. The proposed algorithm uses a multi-hop fashion of data forwarding from cluster head to the base station resulting in reduced energy utilization.

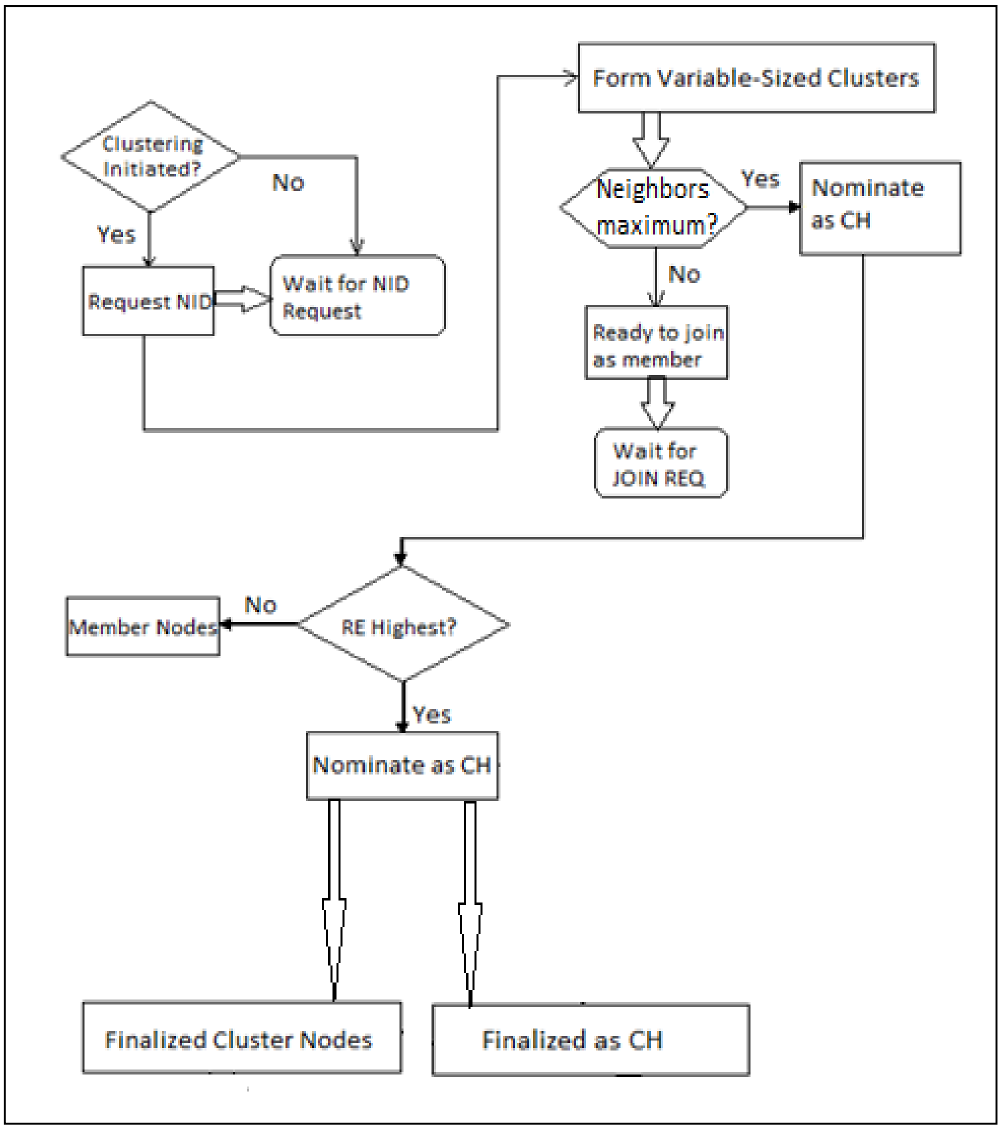


Figure 4: Mechanism of cluster head selection in the proposed algorithm

### B. *Cluster Head Selection*

The cluster head is elected based on the clustering factor (figure 4), which is the combination of residual energy and the number of neighbors of a particular node within a cluster. Residual energy is defined as the energy remaining within a particular node after some number of rounds. This is generally believed as one of the main parameter for CH selection in the proposed algorithm. A neighboring node is a node that remains closer to a particular node within one hop distance. LEACH selects cluster head only based on residual energy, but in the proposed algorithm an additional parameter is included basically to elect the cluster head properly, thereby to reduce the node death rate. The main characteristic feature of the proposed algorithm compared to LEACH is that, the base station does not involve in clustering process directly or indirectly. A node with highest clustering factor is selected as cluster head for the current round. This is generally significant in mobile environment, when the sensor nodes move, the number of neighbors vary which should be taken into account but it is barely not concentrated in the LEACH clustering mechanism.

### C. *Alternate Crisis Hindrance Node*

In a cluster with large number of nodes, cluster crisis does not affect the overall performance of the wireless sensor system. But in the case of network with less number of nodes, cluster crisis greatly affects the wireless sensor system. Care should be done when cluster head selection process by applying alternate recovery mechanisms. In addition to the regular cluster head, additional cluster node is assigned the task of secondary cluster head, and the particular node is called as crisis hindrance node. Generally the cluster collapses when the cluster head fails. In such situations, crisis hindrance node act as cluster head and recovers the cluster. The main characteristic feature of the proposed algorithm is that, the crisis hindrance node solely performs the function of recovery mechanism and does not involve in sensing process. In case of LEACH, the distribution and the loading of CHs to all nodes in the networks is not uniform by switching the cluster heads periodically. Hence, there is a maximum probability of a cluster to be collapsed easily, but it can be avoided in the proposed algorithm with the help of crisis hindrance node.

## 5. SIMULATION RESULTS AND DISCUSSIONS

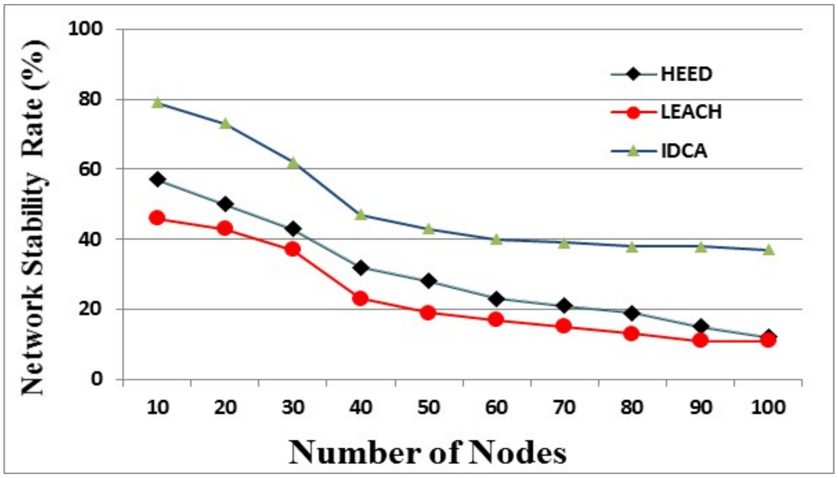


Figure 5: Comparison of Network Stability Rate

Figure 5 shows the comparison of network stability rate with the number of nodes for LEACH, HEED and IDCA. Initially, with 10 sensor nodes, the network stability rate of LEACH, HEED and IDCA are 46%, 57% and 79% respectively. Similarly, for 100 sensor nodes, the network stability rate of LEACH, HEED and IDCA are 11%, 12% and 37% respectively. Ultimately, the network stability rate of the proposed IDCA algorithm is better when compared to LEACH and HEED.

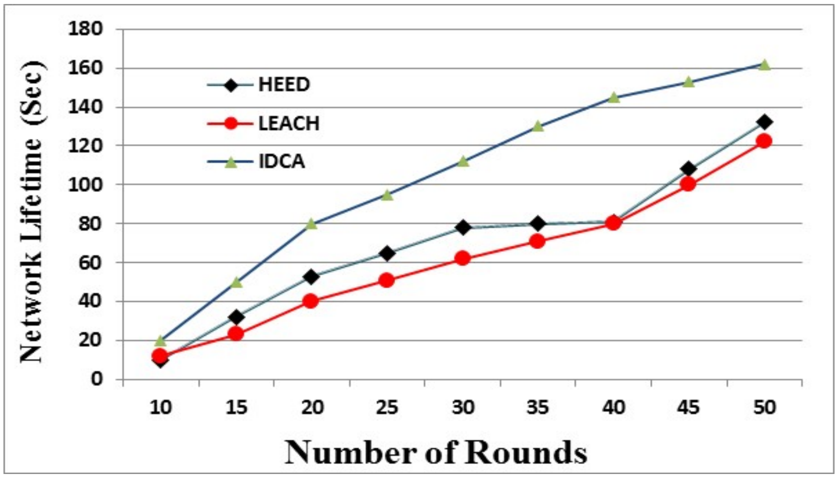


Figure 6: Comparison of Network Lifetime

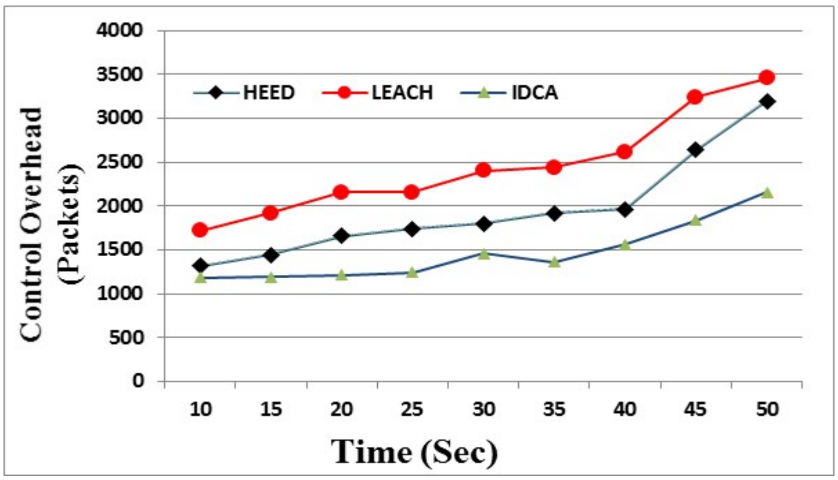


Figure 7: Comparison of Control Overhead

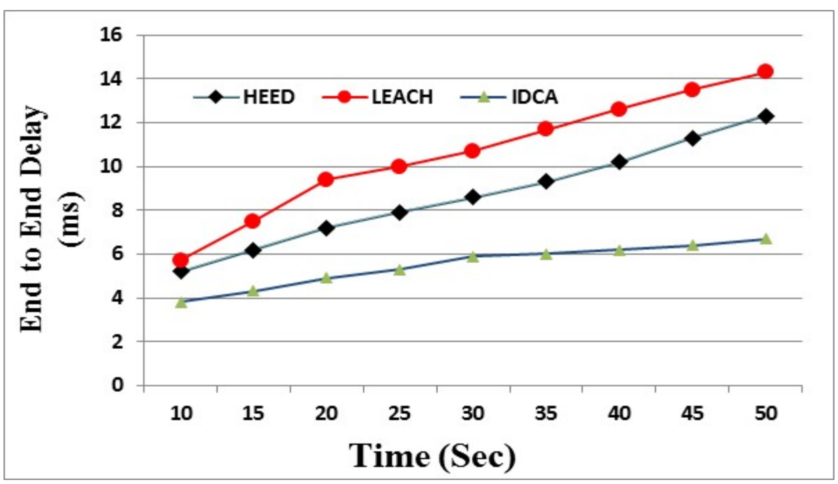


Figure 8: Comparison of End to End Delay

Figure 6 shows the comparison of network lifetime with the number of rounds for LEACH, HEED and IDCA. Initially, at 10 rounds, the network lifetime of LEACH, HEED and IDCA are 12 seconds, 10 seconds and 20 seconds respectively. Similarly, for 50 rounds, the network lifetime of LEACH, HEED and IDCA are 122 seconds, 132 seconds and 162 seconds respectively. Eventually, the network lifetime of the proposed IDCA algorithm is improved when compared to LEACH and HEED. Figure 7 shows the comparison of control overhead with time for

LEACH, HEED and IDCA. Initially, at 10 seconds, the control overhead of LEACH, HEED and IDCA are 1720 packets, 1320 packets and 1180 packets respectively. Similarly, for 50 seconds, the control overhead of LEACH, HEED and IDCA are 3460 packets, 3200 packets and 2160 packets respectively. Ultimately, the control overhead of the proposed IDCA algorithm is reduced when compared to LEACH and HEED.

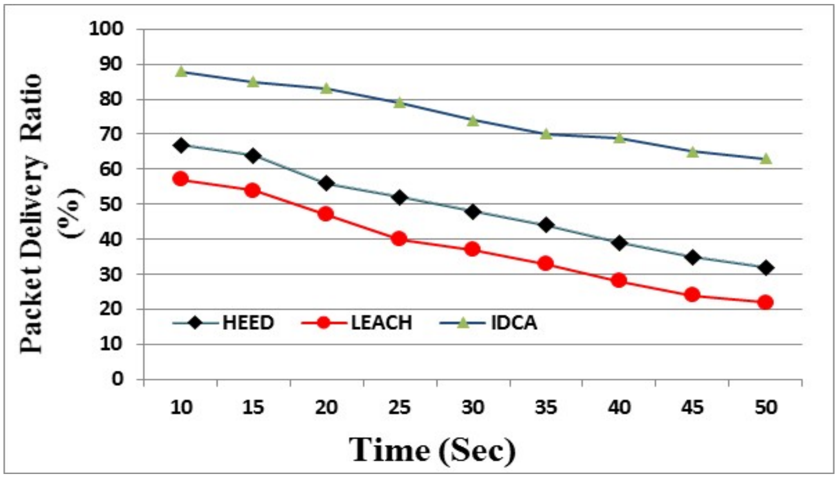


Figure 9: Comparison of Packet Delivery Ratio

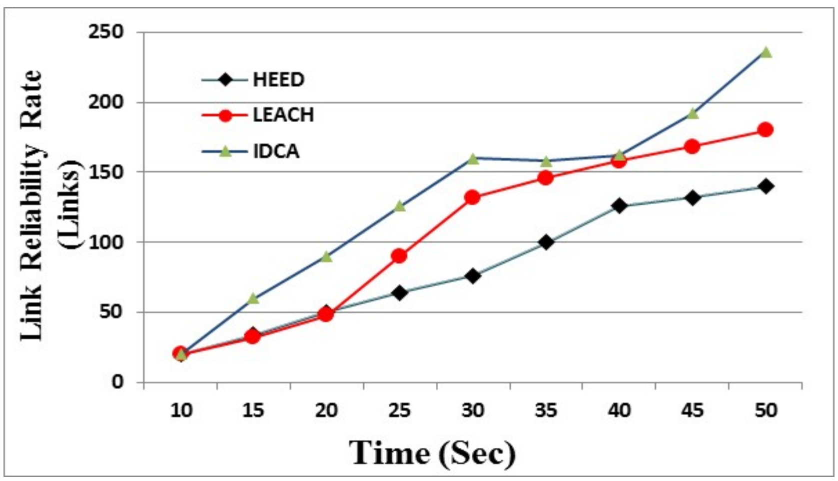


Figure 10: Comparison of Link Reliability Rate

Figure 8 shows the comparison of end to end delay with time for LEACH, HEED and IDCA. Initially, at 10 seconds, the end to end delay of LEACH, HEED and IDCA are 5.7 msec, 5.2 msec and 3.8 msec respectively. Similarly, for 50 seconds, the end to end delay of LEACH, HEED and IDCA are 14.3 msec, 12.3 msec and 6.7 msec respectively. Ultimately, the end to end delay of the proposed IDCA algorithm is reduced when compared to LEACH and HEED. Figure 9 shows the comparison of packet delivery ratio with time for LEACH, HEED and IDCA. Initially, at 10 seconds, the packet delivery ratio of LEACH, HEED and IDCA are 57%, 67% and 88% respectively. Similarly, for 50 seconds, the packet delivery ratio of LEACH, HEED and IDCA are 22%, 32% and 63% respectively. Eventually, the packet delivery ratio of the proposed IDCA algorithm is better when compared to LEACH and HEED. Figure 10 shows the comparison of link reliability rate with time for LEACH, HEED and IDCA. Initially, at 10 seconds, the link reliability rate of LEACH, HEED and IDCA is 20. Similarly, for 50 seconds, the link reliability rate of LEACH, HEED and IDCA are 180, 140 and 236 respectively. Ultimately, the link reliability rate of the proposed IDCA algorithm is improved when compared to LEACH and HEED.

## 6. CONCLUSION AND FUTURE WORK

This paper gives a brief introduction on clustering process in wireless sensor networks. A study on the well evaluated distributed clustering algorithm Low Energy Adaptive Clustering Hierarchy (LEACH) is described artistically. To overcome the drawbacks of the existing LEACH algorithm, a model of distributed layer-based clustering algorithm is proposed for clustering the wireless sensor nodes. The proposed distributed clustering algorithm is based on the aggregated data being forwarded from the cluster head to the base station through cluster head of the next higher layer with shortest distance between the cluster heads. The selection of cluster head is based on the clustering factor, which is the combination of residual energy and the number of neighbors of a particular node within a cluster. Also each cluster has a crisis hindrance node. The proposed distributed clustering algorithm is contrasted with the existing clustering algorithms LEACH and HEED. The proposed clustering algorithm shows a betterment in Network stability, Network lifetime, Packet delivery ratio and Link reliability. End to end delay and Control overhead is greatly reduced as per the simulation results.

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