ASSESSMENT OF CLUSTERING CONSTRAINTS AND APPLICATIONS OF DENSE WSN

A MONOGRAPH

Written By

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Module 1

DECENTRALIZED CLUSTERING ALGORITHMS FOR DENSE WIRELESS SENSOR NETWORKS

Wireless Sensor Network (WSN) is an emerging and very interesting technology applied to different applications. WSNs are networks in which thousands of small and battery powered nodes communicate with each other. A WSN consists of number of spatially distributed nodes which are interconnected without the use of wires. Each node is connected with one or more sensors. Each sensor node consists of a radio receiver, a microcontroller and a battery. The WSN is mainly used in area monitoring, environmental monitoring, industrial monitoring, waste water monitoring, structural monitoring, etc. (Figure 1.1). The major advantages of these networks: they avoid wiring problems and it can be accessed through centralized control.

In order to reduce the data transmission time and energy consumption, the sensor nodes are grouped into a number of small groups called clusters. The grouping of sensor nodes is known as clustering (Figure 1.2). Every cluster has a leader which is known as cluster head (CH). A CH is also one of the sensor nodes which have higher capabilities than other sensor nodes. The cluster head is selected by the sensor nodes in the respective cluster. CHs may also be pre-assigned by the user. The advantages of clustering are that it transmits the aggregated data to the sink or base station. It provides scalability for large number of nodes and reduces energy consumption.

Clustering can be classified into three types: centralized clustering, distributed clustering and hybrid clustering. The centralized clustering is the one in which the cluster head is fixed. The remaining nodes in the cluster act as a member nodes. Distributed clustering is the one in which the cluster head is not fixed. The cluster head keeps on changing form node to node based n on some parameters. Hybrid clustering is the one which is formed by the combination of the centralized clustering and the distributed clustering.

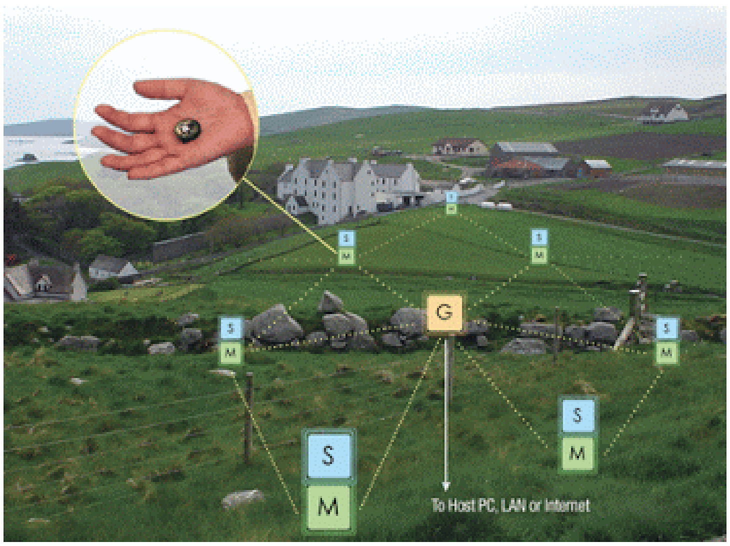

Figure 1.1: Application fields of Wireless Sensor Network for habitat monitoring

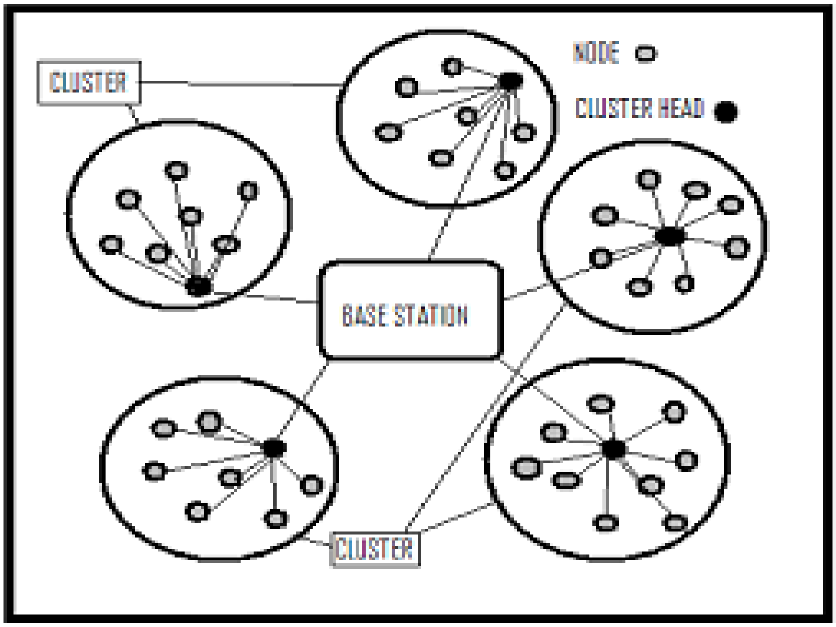

Figure 1.2: Mechanism of Cluster Formation

In centralized clustering, the cluster head is fixed. Because of this, when the cluster head becomes dead, the whole cluster gets collapsed. Hence, there is no reliability in centralized clustering. Distributed clustering provides reliability of data

Even when the cluster head fails. The network fails only when all the nodes fail. The distributed clustering is commonly used in WSNs because it provides better collection of data and reliability. In addition to clustering algorithms, there are many routing algorithms available in wireless sensor networks. The routing protocols are divided into flat-based routing, hierarchical-based routing and location-based routing depending upon the network structure (Few examples are: MCFA, IDSQ, CADR, COUGAR, ACQUIRE, MECN, SOP, VGA, HPAR, TTDD, GAF, GEAR, MFR, DIR, GEDIR, GOAFR, SPAN, etc.).Decentralized clustering is the one in which the cluster head changes from one node to another depending on the resources of the nodes. In this section, a comparative study of various available decentralized clustering algorithms for WSNs is presented.

Linked Cluster Algorithm (LCA): The Linked Cluster Algorithm (LCA) is a decentralized clustering algorithm which avoids communication collisions among nodes. It uses TDMA frames for inter-node communication. Each frame has slot for each node in the network for communication. In LCA, every nodes requires 2n time slots, where 'n' is the number of nodes in the network. If a node 'x' has the highest identity among all nodes within one wireless hop of it or does not have the highest identity in its one hop neighbourhood, but there exists at least one neighbouring node 'y' such that 'x' is the highest identity node in y's one hop neighbourhood, it becomes a cluster-head. Basically, the LCA approach was designed to use in the networks having less than 100 nodes. In such small networks, the delay between the node transmissions is minor and may be accepted.

Algorithm for Cluster Establishment (ACE): ACE is a highly uniform cluster formation, self-organizing, efficient coverage, lesser overlapping and emergent cluster forming algorithm for WSNs. This is scale-independent and completes in time proportional to the deployment density of the nodes regardless of the overall number of nodes in the network. ACE requires no knowledge of geographic location and requires only small amount of communication overhead. The main concept of ACE is to assess the potential of a cluster node as a CH before becoming a CH and steps down if it is not the best CH at the moment. The two logical steps in ACE algorithm are "spawning" of new clusters and "migration" of existing clusters.

Spawning is the process by which a node becomes a CH. During spawning, when a node decides to become a CH it sends an invitation to its neighbours. The neighbouring nodes accept such invitation and become a follower of new CH. The main characteristic feature of ACE is that, a node can be a follower of more than one CH. During migration, the best candidate for being CH is selected. Each CH will periodically check all its neighbours to find which node is the best candidate to become a CH for the cluster. The best candidate is the node which has greatest number of follower nodes with lesser amount of overlap with the existing clusters. Once the best CH is determined by the current CH, it will promote the best candidate as the new CH and steps down from its CH position. Thus, the position of the cluster tends to migrate towards the new CH and some of the former follower nodes of the old CH are no longer part of the clusters, while some new nodes near the new CH becomes new followers of the cluster. Each time that an action can be initiated for a node is called node's iteration. In ACE, a node can have three possible states: it can be unclustered, clustered or it may be a CH. In the beginning of the protocol, all nodes are unclustered. In further iterations the node decides and becomes either a clustered node or a CH.

The idea is to further iterate in order to increase the regularity of cluster layout. ACE exhibits perfect scalability. The protocol takes a fixed amount of time O(d) to complete regardless of the total number of nodes in the network, where 'd' is the estimated average degree (number of neighbours) of a node in the network. ACE is fast, robust against packet loss and node failure, thereby efficient in terms of communication. It uses only local communication between the nodes and shows a good demonstration of flexibility compared to emergent algorithms in large-scale distributed systems.

Hausdroff Clustering (HC): In a decentralized clustering algorithm nodes make autonomous decisions. HC assumes that nodes use traditional RTS/CTS based collision avoidance mechanisms. In this algorithm, once cluster formations take place it remains same throughout the network lifetime. Moreover, to evenly use the energy among all the nodes, CH is rotated among cluster members. At the beginning, each node sends a topology discovery message with the lowest power level to find all its neighbours. Then, the base station (BS) appoints an initiator for starting the clustering operation. The initiator sends a clustering message and waits for join-requests from neighbouring nodes. It then admits cluster members according to the clustering conditions. If the applying node receives an admission message, it sends back a confirmation message. On receiving the confirmation message, the initiator updates its membership list and broadcasts a membership update message with a higher power level for informing neighbouring clusters. If the candidate node is rejected by all its neighbouring clusters, it organizes a new cluster with itself being the initiator. For each cluster, a node with maximum residual energy is selected as the CH, which is also the one with minimum root mean-square distance to its neighbours. In each beginning of a round, the old CH carries out the greedy algorithm and selects the new one. After the new CH is selected, the old one will announce with the lowest power level within the cluster. The new CH broadcasts a message with a higher power level to its neighbouring CHs and gets itself connected for routing. This algorithm maximizes the lifetime of each cluster in order to increase the lifetime of the system. CH selection is basically based on the residual energy of the sensor nodes and also uses the proximity of neighbours as a secondary criterion for improving energy efficiency.

Ring-structured Energy-efficient Clustering Algorithm (RECA): Clustering methods have reduced the conservation of energy in WSNs. RECA mainly focuses in prolonging the network lifetime. This algorithm uses deterministic CH management algorithm to evenly distribute the workload among the nodes within a cluster. Nodes within a cluster make local decisions on the length of their duty cycle according to their remaining energy supply. This shows that all nodes deplete their energy supply at approximately the same time regardless of the initial amount of energy in their batteries. This algorithm is efficient in managing energy in a wide range of networks settings.

Low Energy Adaptive Clustering Hierarchy (LEACH): LEACH is a clustering mechanism that distributes energy consumption all along its network, the network being divided into clusters, CHs which are purely distributed in manner and the randomly elected CHs, collect the information from the nodes which are coming under its cluster. It forms clusters based on the received signal strength (RSS) and uses the CH nodes as routers to the BS. All the data processing such as data fusion and aggregation are local to the cluster. LEACH forms clusters by using a distributed algorithm, where nodes make autonomous decisions without any centralized control. Initially a node decides to be a CH with a probability ‘p’ and broadcasts its decision. Each non-CH node determines its cluster by choosing the CH that can be reached using the least communication energy. The role of being a CH is rotated periodically among the nodes of the cluster in order to balance the load. The rotation is performed by getting each node to choose a random number ‘T’ between 0 and 1.

Since the decision to change the CH is probabilistic, there is a good chance that a node with very low energy gets selected as a CH. When this node dies, the whole cell becomes dysfunctional. Also, the CH is assumed to have a long communication range so that the data can reach the BS from the CH directly. This is not always a realistic assumption since the CHs are regular sensors and the BS is often not directly reachable to all nodes due to signal propagation problems. This algorithm also forms one-hop intra-cluster and inter-cluster topology where each node can transmit directly to the CH and thereafter to the BS. Consequently, it is not applicable to large scale networks.

Two-Level LEACH (TL-LEACH): A new version of LEACH called TL-LEACH, the CH collects data from other cluster members as in original LEACH, but rather than transferring data to the BS directly, it uses one of the CH that lies between the CH and the BS as a relay station. It has two levels of cluster heads (primary CH and secondary CH). The primary CH in each cluster communicates with the secondary CH, and the corresponding secondary CH communicates with the nodes in their sub-cluster. Data fusion can be performed as in LEACH. Additionally, communication within a cluster is scheduled using TDMA time-slots. The organization of a round will consist of first selecting the primary and secondary CHs using the same mechanism as in LEACH, with the probability of being elevated to a primary CH less than that of a secondary node. Communication of data from source node to sink is done in two steps: secondary nodes collect data from nodes in their respective clusters. Data fusion can be performed at this level. Primary nodes collect data from their respective secondary clusters. Data-fusion can also be implemented at the primary CH level. The two-level structure of this algorithm reduces the number of nodes that need to transmit to the BS, thereby effectively reducing the total energy usage.

CLUBS: CLUBS is an algorithm that forms clusters through local broadcast and converge in a time proportional to the local density of nodes. The clustering phenomenon in CLUBS is characterized by the following: First, every node in the network must belong to some cluster. Second, every cluster should be of same diameter. Third, a cluster should have local routing, which means that every node within the cluster should be able to communicate with each other using only nodes within that same cluster. Every nodes starts competing to form a cluster by choosing random numbers from a fixed integer range [0, R]. Each node counts down from that number silently. If it reaches zero without being interrupted, the node becomes a CH and recruits its local neighbourhood in to its cluster by broadcasting a “recruit message“. The nodes that get recruited are generally called “followers”. Since CLUBS allows overlapping, follower nodes keep listening to additional recruit messages and can be follower of more than on CH.

If a node that is competing to become a CH detects a collision or received a garbled message, it becomes a follower node and assumes that multiple CHs attempted to recruit it at the same time. It can find out its CH later. The algorithm does not terminate unless all nodes in the network join some cluster as a CH or as a follower. CLUBS can be implemented in the asynchronous environment without losing efficiency and simplicity. Furthermore, CLUBS satisfies many constraints that are common in other distributed environment such as limited or no topology knowledge or access to global IDs. The major problem of CLUBS algorithm is the clusters having their CHs within one-hop range of each other. If this is the case, both clusters will collapse and CH election process will restart.

Hybrid Energy-Efficient Distributed Clustering (HEED): HEED is a decentralized algorithm which selects the CH based on both residual energy and communication cost. Basically HEED was proposed to avoid the random selection of CHs. This algorithm gets executed in three subsequent phases: Initialization phase, repetition phase and finalization phase. Initialization phase, in which the initial CH nodes percentage will be given to the nodes.Repetition phase, in which until the CH node was found with least transmission cost and finalization phase, in which the selection of CH will be properly finalized.

Multi-hop Overlapping Clustering Algorithm (MOCA): MOCA is a randomized, distributed multi-hop overlapping clustering algorithm introduced for organizing the sensors into overlapping clusters. The goal of this clustering process is to ensure that each node is either a CH or within k-hops from at least one CH, where ‘k’ is a pre-set cluster radius. The algorithm initially assumes that each sensor in the network becomes a CH with probability ‘p’. Each CH then advertises itself to the sensors within its radio range. This advertisement is forwarded to all sensors that are no more than k-hops away from the CH. A node sends a request to all CHs to join their clusters.

In the join request, the node includes the ID of all CHs it heard from, which implicitly implies that it is a boundary node. The CH nomination probability (p) is used to control the number of clusters in the network and the degree of overlap among them. By choosing an appropriate value of 'p' this algorithm achieves an excellent cluster count and overlapping degree.

Fast Local Clustering Service (FLOC): This decentralized clustering algorithm is suitable for clustering large-scale WSNs. It is fast, scalable, produces non-overlapping and approximately equal-sized clusters. FLOC achieves locality: effects of cluster formation and faults or changes at any part of the network are contained within a predetermined radius. FLOC exploits the double-band nature of wireless radio-model. A node can communicate reliably with the nodes that are in the inner band (i-band) range and unreliably with the nodes in its outer-band (o-band) range. I-band nodes will be affected by very little interference communicating with the CH, while message from o-band nodes may have maximum probability of getting lost. FLOC favours i-band membership in order to increase the robustness of the intra-cluster traffic. FLOC achieves clustering in O(1) time regardless of the size of the network. It also exhibits self-healing capabilities since o-band nodes can switch to i-band node in another cluster. Also it achieves clustering in constant time regardless of the network size and in a local manner. It also achieve locality, in that each node is only affected by the nodes within two units.

Distributed Weight-Based Energy-Efficient Hierarchical Clustering (DWEHC): Distributed Weight-Based Energy-Efficient Hierarchical Clustering is a decentralized clustering algorithm, which generates well balanced clusters and shows drastic improvements in performance over HEED. The clustering process terminates in O(1) iterations and does not depend on network topology on size. Each node first locates its neighbours, and then calculates its weight which is based on its residual energy and distance to its neighbours. The node which is having more weight in a neighbourhood may become a CH. Neighbouring nodes will join the clustered hierarchy as member nodes. At this stage the nodes are considered as first-level members since they have a direct link to the CH. A node progressively adjusts to such membership in order to reach a CH with minimum amount of energy. Basically, a node checks with its non-CH neighbours to find out their minimal cost for reaching a CH. Given the knowledge of the node about the distance to its neighbours, it can assess whether it is better to stay as a first-level member or become a second-level one by reaching the CH over a two-hop path. It is worth nothing that by doing so, the node may switch to a CH other than its original one. The process is iterated until the nodes settle in most energy-efficient topology. DWEHC shows some features on forming a clustered network: A node is either a CH or a member in the cluster but the level of the node depends on the cluster range and the minimum energy path to the CH, each cluster has a minimum energy topology, and a CH has a limited number of member nodes. The algorithm constructs multilevel clusters and the nodes in each cluster reach the CH by relaying through other intermediate nodes. The leading advantage of DWEHC over HEED is that, it shows a great improvement in both intra-cluster energy consumption and inter-cluster energy consumption. Table 1.1, shows the comparison of various presented decentralized clustering algorithms for wireless sensor networks.

Table 1.1: Comparison of decentralized clustering algorithms

Decentralized Clustering Algorithm	Time Complexity	Node Mobility	Cluster Overlap	In-Cluster Topology	Cluster Count	Cluster Head Selection
LCA	Variable	Possible	No	1-hop	Variable	Random
ACE	Constant	Possible	Yes	K-hop	Variable	Random
HC	Variable	Possible	No	1-hop	Variable	Connectivity
RECA	Constant	No	No	1-hop	Variable	Random
TL-LEACH	Constant	Possible	No	1-hop	Variable	Random
CLUBS	Variable	Possible	Yes	2-hop	Variable	Random
HEED	Constant	Stationary	No	1-hop	Variable	Random
LEACH	Constant	Fixed BS	No	1-hop	Variable	Random
MOCA	Constant	Stationary	Yes	K-hop	Variable	Random
FLOC	Constant	Possible	No	2-hop	Variable	Random
DWEH	Constant	Stationary	No	K-hop	Variable	Random

A growing list of civil and military applications can employ WSNs in hostile and remote areas. It can be used by the military for a number of purposes such as monitoring militant activity in remote areas and force protection. WSNs are also used for the collection of data for monitoring of environmental information. Most recent researches have begun to consider a wider range of aspects such as wireless link reliability, real-time capabilities and quality-of-service (QoS). Clustering provides scalability, energy saving, reliability, etc. In this module, a comparative analysis of different available decentralized clustering algorithm has been done. A comparative analysis of various decentralized algorithms with their parameters has been detailed elaborately. Future works may concentrate on developing a better clustering algorithm.

Module 2

CLUSTERING METHODOLOGY BASED ON CAPACITY

Generally a wireless sensor node consists of low power processor, tiny memory, radio frequency module, various kinds of sensing devices and limited powered batteries which finds applicable in target tracking, environmental monitoring and oceanography (figure 2.1). Much of energy consumption happens during wireless communications. The energy consumption when transmitting one bit of data equals to several thousands of cycles of CPU operations. Hence the energy efficiency of a wireless communication protocol brutally affects the energy efficiency and lifetime of the network. Many researchers have projected several algorithms for WSNs to improve energy consumption and network lifetime. Since these wireless sensor devices are power-constrained, long-distance communications are not encouraged. Thereby direct communication between the nodes and base station is generally avoided. A proficient way is to arrange the network into several clusters and each individual cluster has a cluster-head (CH). CH is one of the sensor nodes which is affluent in resources. Sensor nodes send their sensed information to the CH during their respective TDMA time-slots. The CH performs data aggregation process and forwards the aggregated data to base station (BS). Clustering follows some advantages like network scalability, localizing route setup within the cluster, uses communication bandwidth efficiently and makes best use of network lifetime. Since clustering uses the mechanism of data aggregation, unnecessary communication between the sensor nodes, CH and BS is avoided. In this module, a model of distributed clustering algorithm is proposed which is based degree of capacity (DOC) of a node within a cluster. The DOC of a node is the combination of three parameters: the number of tasks assigned to a particular node, remaining energy and coverage with neighbouring nodes. The node with highest DOC is selected as a CH for the current round. The primary objective of the proposed algorithm is to attain energy efficiency and extended network lifetime.

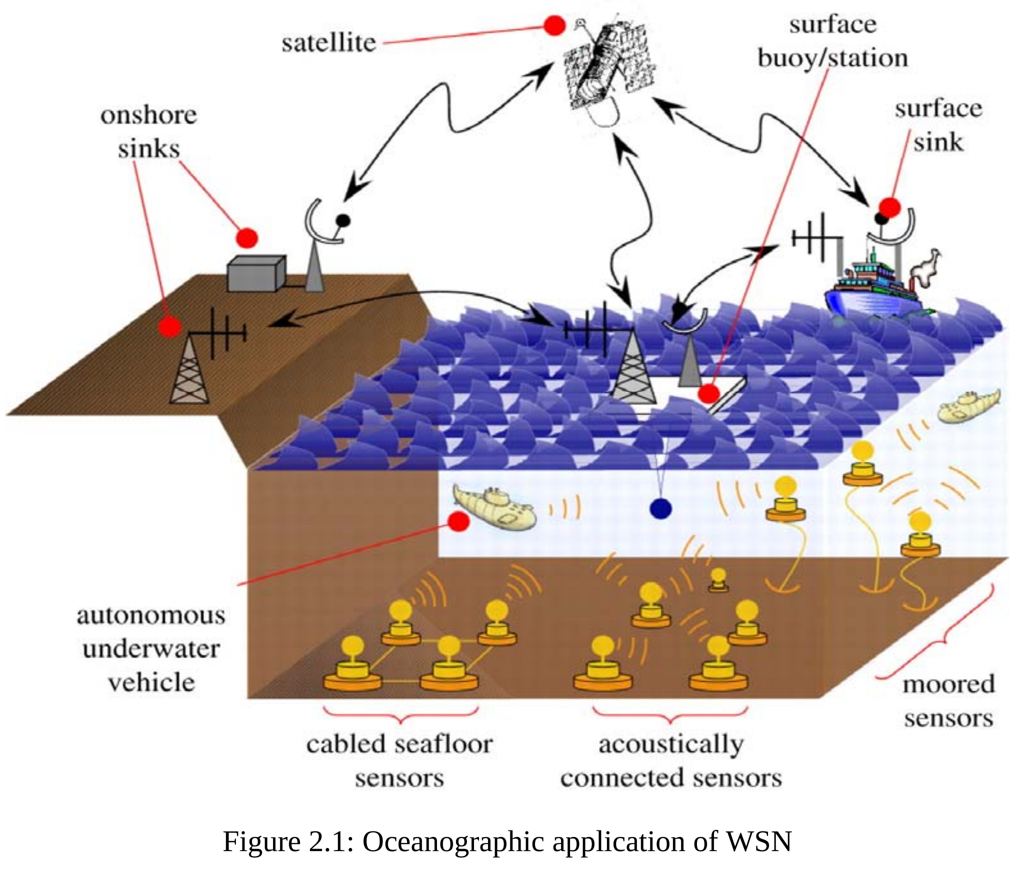

Figure 2.1: Oceanographic application of WSN

2.1 LEACH AND ITS FOLLOWERS

Low Energy Adaptive Clustering Hierarchical Protocol (LEACH) uses the following techniques to accomplish the design goals: randomized, self-configuring, adaptive cluster formation, local control for data transfers, low-energy media access control and application specific data dispensation. LEACH protocol has various rounds and each round has two phases: setup phase and steady state phase. In set up phase, it provides cluster formation in adaptive manner and in the steady state phase data transfer takes place. LEACH uses a TDMA to reduce inter-cluster and intra-cluster collisions. The energy utilization of the information gathered by the sensors node to reach the BS depends on the number of cluster heads and radio range.

LEACH-F: In this algorithm the number of clusters will be permanent throughout the network lifetime and the cluster heads are rotated within the cluster. Steady state phase of LEACH-F is alike as that of LEACH. LEACH-F may or may not offer energy saving and this protocol does not provide flexibility to sensor nodes' mobility.

LEACH-C: LEACH cluster formation algorithm has the disadvantages of having no guarantee about the number of cluster head nodes. Since the clusters are adaptive, there is deprived clustering set-up during a round. However, by using a central control mechanism to form clusters can produce better clusters by distributing the cluster head nodes throughout the network.

LEACH-B: This algorithm operates in the following phases: cluster formation, cluster head selection and data transmission. Every sensor node chooses its cluster head by evaluating the energy dissipated in the pathway between the last receiver and itself. It provides better energy efficiency in comparison with LEACH.

LEACH-ET: The cluster will adjust only when one of the following conditions is satisfied: Energy consumed by anyone of the CHs reaches energy threshold (ET) in one round, every sensor node should have the knowledge of the energy threshold (ET) value. During the initial phase, if anyone of the cluster head nodes dies, it should have the energy dissipated value and compares the dissipated value with the energy threshold (ET) value.

Energy–LEACH: This mechanism provides improvement in selection of cluster heads of LEACH protocol. It makes residual energy of a node as the main factor which decides whether these sensor nodes turn into the cluster head or not in the next round. E-LEACH helps a large in the cluster head election procedure.

TL-LEACH: This algorithm works in three phases: cluster-head casing, cluster setup and data transmission phase. This protocol is an improvement of LEACH where some of the cluster heads elected during setup phase in LEACH are chosen as the level-2 cluster heads (CHs), which communicates with the base station.

MH-LEACH: This protocol improves the communication mode from a single hop to multi hop between cluster head and base station. In LEACH, every cluster head directly communicates with sink ignoring the distance between the sink and the cluster head. The modified form, MH LEACH protocol adopts an optimal path between the base station and cluster head; thereby multi hop communication takes place among cluster heads.

ACHTH–LEACH: ACHTH–LEACH was proposed to improve the shortcomings of LEACH. The clusters are set up on the basis of Greedy k-means algorithm. The cluster heads are elected by considering the residual energy of sensor nodes, which may adopt two hop transmissions to reduce the energy spent on forwarding data to the BS. The performance of ACHTH-LEACH can be further improved if some parameters and threshold values are optimized.

MELEACH-L: This is an energy-efficient multi-channel routing protocol for wireless sensor networks. With the aim of controlling the size of each cluster and separating CHs from backbone nodes, MELEACH-L manages the channel assignment amid neighbouring clusters and co-operation among CHs during data collection.

2.2 THE PROPOSED CLUSTERING ALGORITHM

The proposed clustering algorithm 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 two distinguishing features. First, the proposed algorithm uses variable transmission power. Nodes nearer to CH use lesser transmission power and nodes far away from CH use extra power for transmission from nodes to CH or vice versa, which can lessen considerable power. Second, CH sends one message for every cluster nodes but many existing algorithms transmits numerous messages for cluster-setup.

2.3 DISCUSSIONS ON CH SELECTION

The main activity in a WSN is to effectively select a CH. This is achieved by using various techniques. In the proposed algorithm, CH selection is accomplished with the use of the following parameters (figure 2.2).

Highest Coverage: In a network of N nodes, each node is assigned an exclusive Node Identity (NID) represented by n, where n=1, 2, 3…., N. The NID just serves as 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 and these layers are assigned with Layer Number (LN). LN is an integer number beginning from zero. CH gets LN0, nodes adjacent the CH in the next layer are assigned LN1, and so on. In LEACH, the coverage of a sensor node is not taken into account. This is essentially significant when a sensor network is used for remote monitoring applications. The nodes with highest coverage between the cluster nodes are given highest priority to become a CH. Basically HEED was proposed to avoid random selection of CHs. Though LEACH was more energy efficient, the main drawback is the arbitrary selection of CH. In HEED, the selection of CH is essentially based on residual energy and communication cost of the nodes. Here the lack of the parameter coverage leads to a main drawback. To overcome these problems, coverage among the nodes is considered to be one of the main parameter in the proposed algorithm.

Highest Remaining Energy: Remaining energy is defined as to energy remaining within a particular node after some number of rounds. This is generally considered as one of the main parameter for CH selection in the proposed algorithm. LEACH uses much energy for communication among nodes and CHs. It tries to distribute the loading of CHs to all nodes in the network by switching the cluster heads periodically. Due to two-hop structure of the network, a node far from CH will have to consume additional energy than a node nearer to CH. This introduces an uneven distribution of energy among the cluster members, disturbing the total system energy and remaining energy. Node death rate is also directly proportional to the remaining energy. It is the measure of the number of nodes die over a time period, from the beginning of the process. When the data rate increases the node death rate also increases. The networks formed by LEACH show periodical variations in the data collection time. This is due to the selection function dependent on the number of data collection process. Since the CH selection of LEACH is a function of the number of completed data collection processes, the number of cluster varies periodically. The same process prevails also in HEED due to enlarged data collection. This increases the node death rate. Hence, remaining energy is considered as one of the important parameter for CH selection in the proposed algorithm.

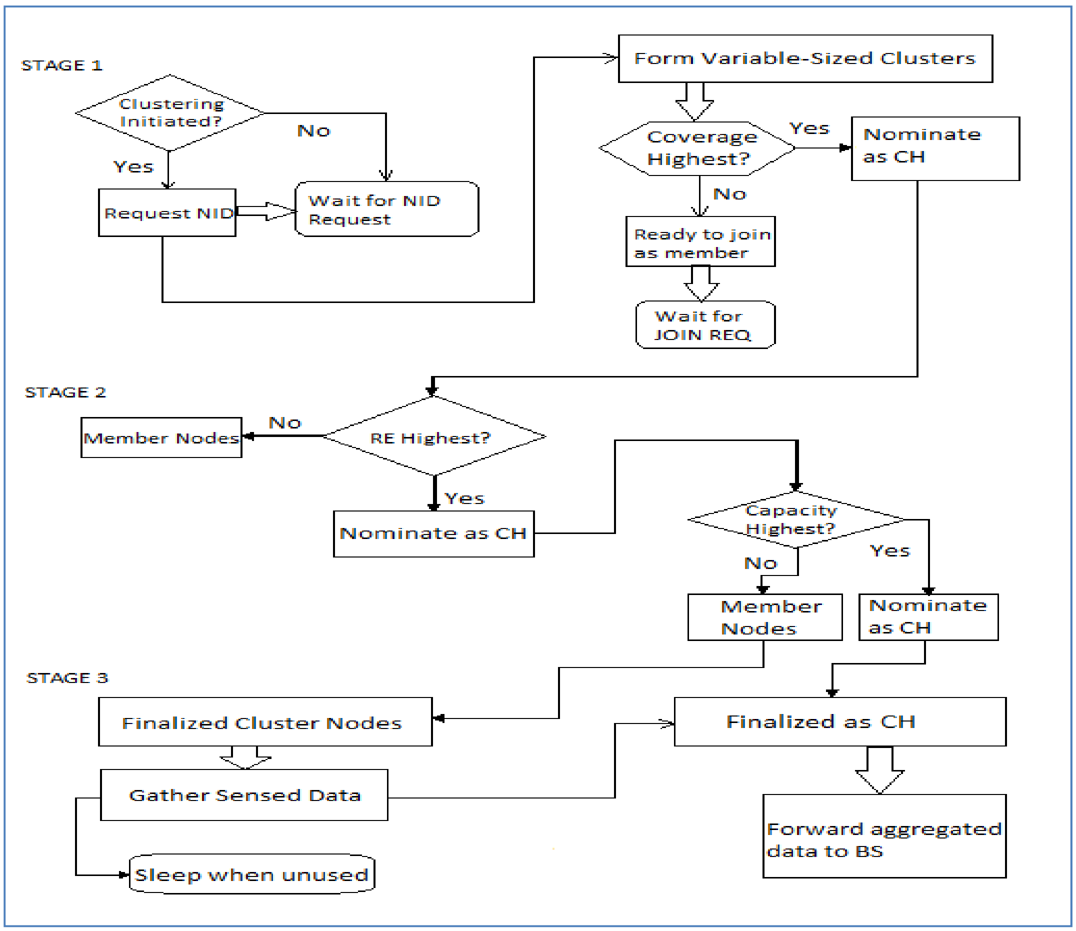

Figure 2.2: Cluster formation in the proposed algorithm

*Highest Capacity:*Capacity of a node is the measure of the amount of data processing it can handle compared to other nodes. A node with highest capacity is given priority to become a CH. LEACH uses more energy for communication between nodes and CHs. It tries to distribute the loading of CHs to all nodes in the network by switching the cluster heads from time to time. The uneven distribution of energy among the cluster members is avoided in HEED as the CH selection is based on residual energy and communication cost. A node with highest residual energy and communication cost becomes a CH, thus the random selection of CH is avoided. But in the repetition phase, a number of iterations are carried out in order to find the communication cost and selecting a node with better communication cost. This is a peculiar drawback of HEED. In the proposed algorithm, fewer communication energy is required. It uses the concept of variable-transmission power in which the transmission power is variable from the lower edge to the higher edge based on the layers. Also in the proposed algorithm, separation among the layers is optimized to use optimum power for each layer. Hence the node with highest capacity is selected as a CH.

This module 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) and its followers are described artistically. To overcome the drawbacks of these existing algorithms a distributed clustering model has been proposed for clustering the wireless sensor nodes. Based on the degree of capacity (DOC), the algorithm has been formulated to form efficient clusters in a wireless sensor network. The proposed distributed clustering algorithm can show much improvement in communication energy. The performance of the proposed algorithm can show a drastic improvement in the total energy of the wireless sensor system. Nevertheless, the proposed algorithm can greatly minimize the node death rate and thus have prolonged network lifetime. In future, the algorithm will be simulated and compared with two or three existing distributed clustering algorithms.

Module 3

INTEGRATED DISTRIBUTED CLUSTERING METHODOLOGY

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 3.1). 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.

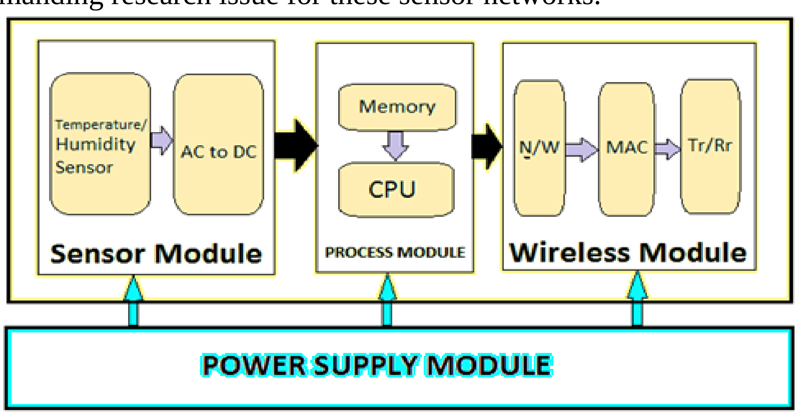

Figure 3.1: Various components of a wireless sensor node

Clustering 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 3.2) 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 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 efficiently and takes advantage of network lifetime.

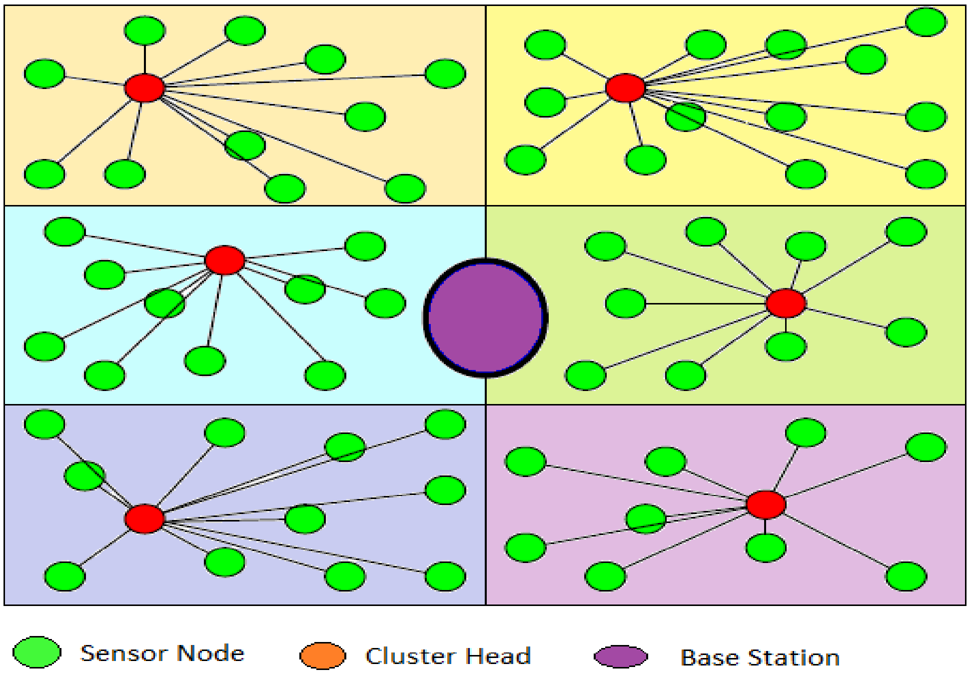

Figure 3.2: Cluster formation in a wireless sensor network

By the data aggregation process, unnecessary communication between sensor nodes, cluster head and the base station is evaded. In this module, 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.

3.1. AN EVALUATION OF LEACH ALGORITHM

LEACH 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 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.

3.2 THE PROPOSED CLUSTERING ALGORITHM

The proposed clustering algorithm 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 neighbours of a particular node within a cluster. Third, each cluster has a crisis hindrance node that does the function of cluster head when the cluster head fails to carry out its work in some conditions.

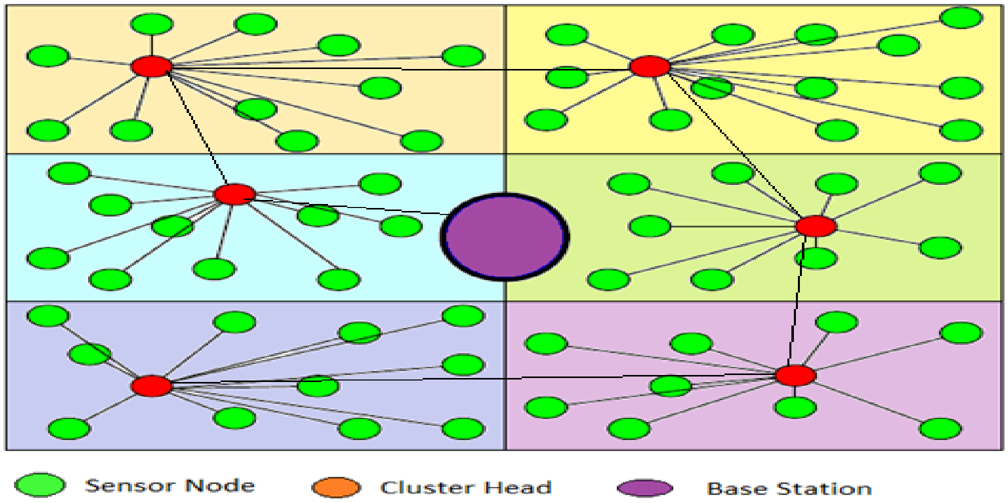

Figure 3.3: Aggregated data forwarding in the proposed algorithm

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 3.3).

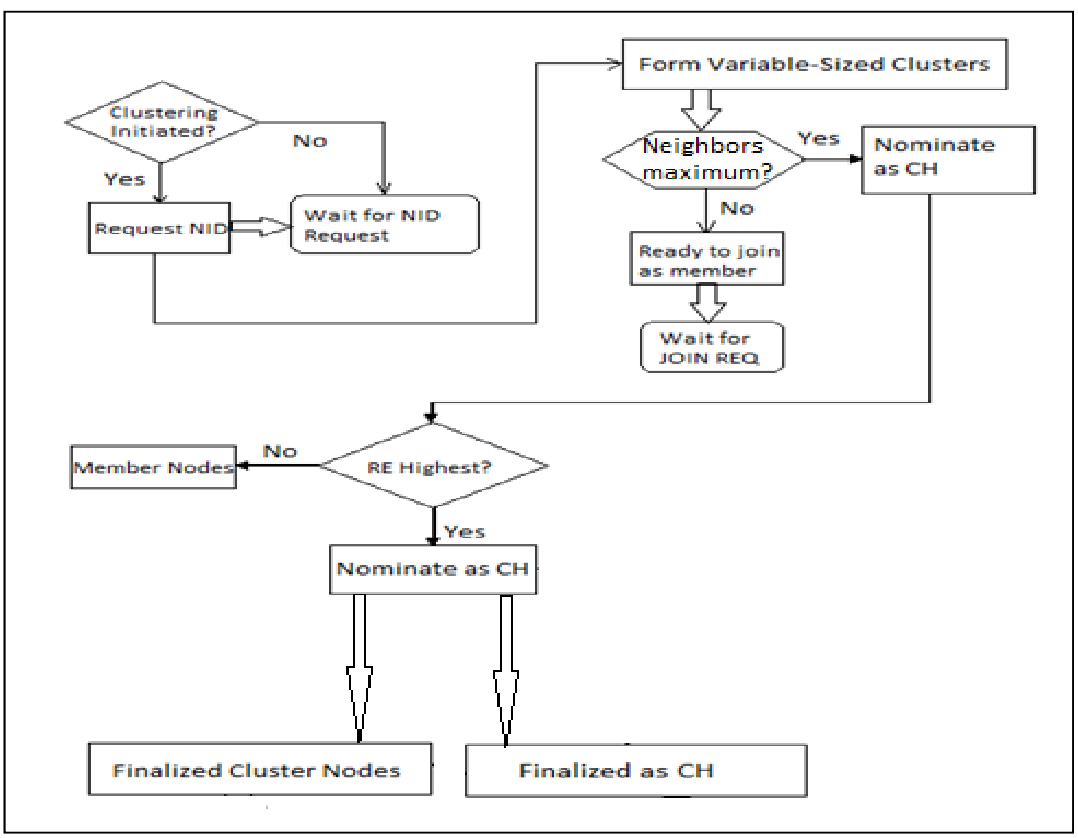

Figure 3.4: Mechanism of cluster head selection in the proposed algorithm

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.

Cluster Head Selection: The cluster head is elected based on the clustering factor (figure 3.4), which is the combination of residual energy and the number of neighbours 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 neighbouring 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 neighbours vary which should be taken into account but it is barely not concentrated in the LEACH clustering mechanism.

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.

This module 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 neighbours of a particular node within a cluster. Also each cluster has a crisis hindrance node. In future, the algorithm will be simulated using the network simulator and the simulated results will be compared with two or three existing distributed clustering algorithms.

Module 4

PERFORMANCE EVALUATION OF DRIP IRRIGATION USING WIRELESS SENSOR NETWORK

A WSN protocol consists of application, transport, network, data link, and physical layers arranged one upon the other along with power management, mobility management and the task management plans arranged in an ordered fashion. Currently two standard technologies available for wireless sensor networks are Zigbee, and Bluetooth both operates in Industrial Scientific and Medical (ISM) band of 2.4 GHz, which provides license free operation for scientific research and study purpose. In general, increase in frequency increases bandwidth which allows high speed data transmission. In-order to decrease the power requirement distance between sensor nodes has to be reduced as possible. Multi-hop communication over the ISM will be promising technique in WSN, since it consumes less power than traditional single-hop communication. A sensor is intelligent to convert physical or chemical readings gathered from the environment into signals that can be calculated by a system. A multi-sensor node is intelligent to sense several magnitude values in the same device. In a multi-sensor, the input variables may be temperature, fire, motion detection sensors, infrared radiation, humidity and smoke. A wireless sensor network could be a functional architecture for the deployment of the sensors used for fire detection and verification. The most imperative factors for the quality and yield of plant growth are temperature, humidity, light and the level of nutrition content of the soil in-addition with the carbon dioxide in the surrounding atmosphere. Constant monitoring of these ecological variables gives information to the cultivator to better understand, how each aspect affects growth and how to achieve maximal crop productiveness. The best possible greenhouse climate modification can facilitate us to advance productivity and to get remarkable energy saving, predominantly during the winter in northern countries. In the past age band, greenhouses it was enough to have one cabled dimension point in the middle to offer the information to the greenhouse automation system.

The arrangement itself was typically simple without opportunities to supervise locally heating, light, ventilation or some other actions which were affecting the greenhouse interior climate. The archetypal size of the greenhouse itself is much larger than it was before, and the greenhouse facilities afford several options to make local adjustments to light, ventilation and other greenhouse support systems. However, added measurement data is also needed to put up this kind of automation system to labour properly. Increased number of measurement points should not dramatically augment the automation system cost. It should also be probable to easily alter the location of the measurement points according to the particular needs, which depend on the definite plant, on the possible changes in the external weather or greenhouse arrangement and on the plant placement in the greenhouse. Wireless sensor network can form a helpful part of the automation system architecture in contemporary greenhouses constructively. Wireless communication is used to transmit the measurements and to establish communicate between the centralized control and the actuators located to the different parts of the greenhouse. In highly developed WSN systems, some parts of the control system has to be implemented on the field in a distributed so that local control loops can be created. WSN is fast, cheap and easy compared to cabled network systems.

Moreover, it is easy to relocate the measurement points when needed by immediately moving sensor nodes from one location to another within a communication range of the coordinator gadget. If the greenhouse vegetation is high and dense, the small and light weight nodes can be hanged up with the branches. WSN is easy to maintain, relatively inexpensive and trouble-free. The only other expense occur only when the sensor nodes run out of batteries and the batteries have to be charged or replaced. Lifespan of the battery can be increased to several years if a proficient power saving algorithm is applied. In this work, the very first steps towards the wireless greenhouse automation system by building a wireless measuring arrangement for that purpose is taken and by testing its feasibility and reliability with a straightforward setup. Figure 4.1 entails the drip irrigation methodology by sensor network.

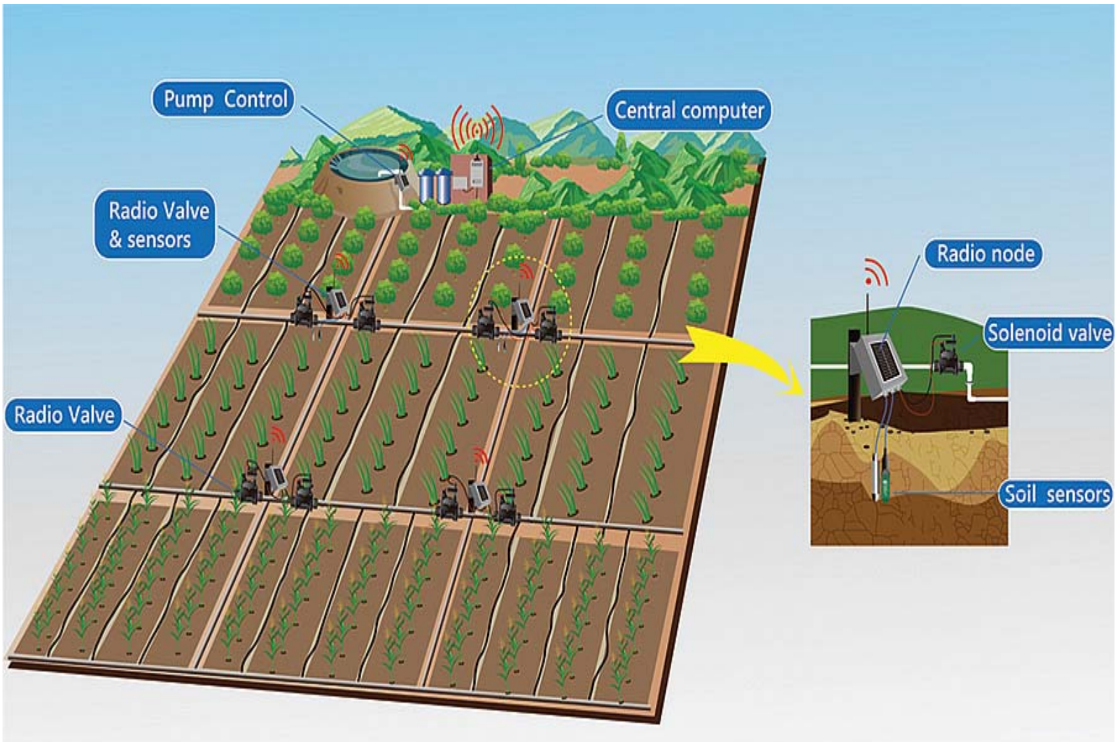

Figure 4.1: Drip Irrigation Methodology by Sensor Network

These greenhouse parameters are generally essential in the case of precision agriculture. In this module, a mechanism for cluster formation for drip irrigation system for precision agriculture has been elaborated. Keeping aside these greenhouse parameters which are essential for cultivation, methodology for cluster formation in drip irrigation system shall be discussed. A distributed clustering mechanism has been employed for cluster formation. Also, few parameters that is necessary for wireless sensor node deployment, for agricultural application has been discussed in the subsequent sections.

4.1 PLANTATION MANAGEMENT USING WSN

For developing an efficient system for agricultural system management, the foremost inputs to the system will be the availability of accurate data's (figure 4.2) like soil properties, agronomic, physicochemical parameters, atmospheric data, etc., Data collection can be made flexible on a day-to-day basis or even hourly basis based on the need. Normal laboratory analysis of above mentioned parameters and manual decision-making take a long time even with the most sophisticated analytical techniques. Most of the samples have to be brought from the field to laboratories to analyze most of the time. By the time the results are available and decisions are taken, the conditions of the farm may change which results in inappropriate decision. Quick and quality decision-making at the farm level will enhance agricultural productivity and quality manifold which further needs accurate and real time properties of the field.

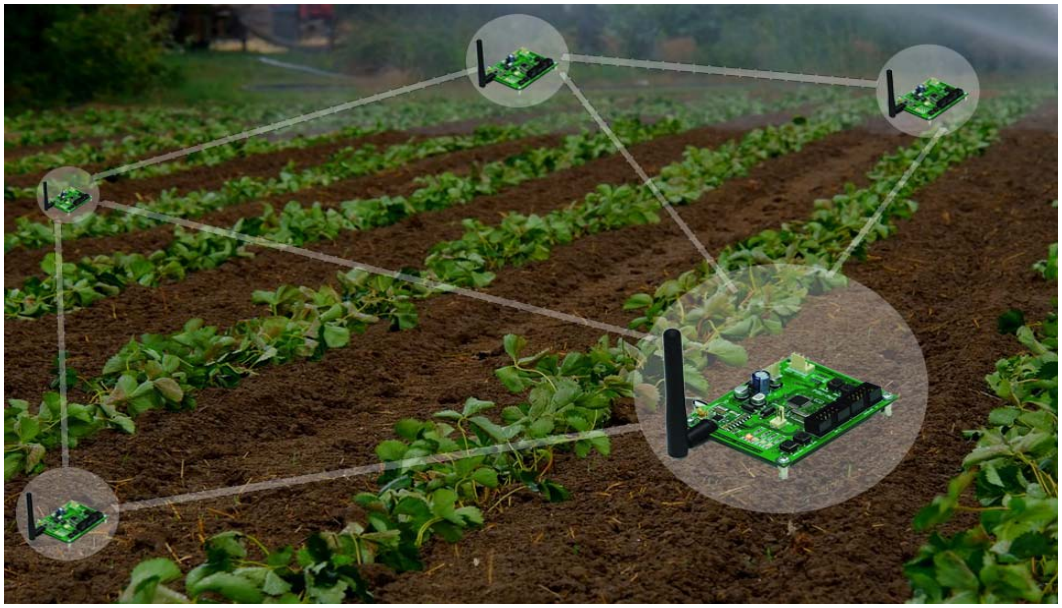

Figure 4.2: WSN in Precision agriculture

Computerized data handling process can handle and analyze several sensor parameters simultaneously which uses large database to compare with pre-sampled with standardized values to make appropriate decision. Monitoring of physical and environmental parameters including soil moisture, soil temperature, nutrition content of the soil, leaf temperature, relative humidity, air temperature, rainfall, vapour pressure and availability of sun light is done through a wireless sensor network. WSN is comprised of distributed sensors to monitor physical, chemical and environmental conditions. WSN integrates sensors, wireless and processing tools which are capable of sensing different physical parameters without any loss in sensed data accuracy. The parameters are processed and wirelessly transmitted to a centralized data storage system through a gateway from where they may be remotely accessed and analysed by the user. The system architecture of a WSN-based system consists of different sensors interfaced to electronic hardware with a suit of data processing tools. The electronic hardware is also equipped with wireless communication modules which allows sensed data to be modulated and transmitted in accordance to a selected protocol. These hardware nodes are called motes in WSN. Each of these motes are interfaced with some set of wireless sensors depending on the applications interest. The sensors may be programmed to sense in a continuous or discrete manner. The needed parameters for precision agriculture have been enumerated in the next section.

4.2 WSN IN PRECISION AGRICULTURE

WSN technology can broadly be applied into three areas of agriculture: a) Fertilizer control, b) Irrigation management and c) Pest management. The following parameters should essentially be accounted before deploying sensor nodes in a wireless sensor field.

The Greenhouse Environment: A contemporary greenhouse can consist of copious parts which contain their own confined climate variable settings. As a result, a quantity of measurement points is also needed. This group of environment is demanding both for the sensor node electronics and for the short-range IEEE 802.15.4 wireless network, in which communication choice is greatly longer in open environments.

Sensors: Speedy response time, squat power consumption and tolerance beside moisture climate, relative humidity and temperature sensor forms an idyllic preference and explanation for the greenhouse environment. Communication among sensor nodes can be carried out by IIC interface. Luminosity can be measured by light sensor, which converts light intensity to equivalent voltage. Unstable output signal is handled by low-pass filter to acquire exact luminosity values. CO_2 measuring takes longer time than other measurements and CO_2 sensor voltage supply have to be within little volts. The carbon dioxide assessment can be read from the ensuing output voltage. Operational amplifier raises the voltage level of weak signal from the sensor.

*Greenhouses:*A greenhouse is a pattern covering the ground frequently used for growth and progress of plants that will revisit the owner's risk, time and capital. This exhibit is mounted with the purpose of caring crop and allowing a better environment to its advancement. This defend is enough to guarantee a higher quality in production in some cases. However, when the chief idea is to achieve a superior control on the horticulture development, it is necessary to examine and control the variables that influence the progress of a culture. The chief role of a greenhouse is to offer a more compassionate environment than outside. Unlike what happens in customary agriculture, where crop conditions and yield depend on natural resources such as climate, soil and others, a greenhouse ought to promise production independent of climatic factors. It is noteworthy to view that even though a greenhouse protects crop from peripheral factors such as winds, water excess and warmth it may root plentiful problems such as fungus and extreme humidity.

*Temperature:*Temperature is one of the main key factors to be monitored since it is unswervingly related to the development and progress of the plants. For all plant varieties, there is a temperature variety considered as a best range and to most plants this range is comparatively varying between 10ºC and 30ºC. Among these parameters of temperature: intense temperatures, maximum temperature, minimum temperature, day and night temperatures, difference between day and night temperatures are to be cautiously considered.

Water and Humidity: An additional significant factor in greenhouses is water. The absorption of water by plants is associated with the radiation. The deficient in or low level of water affects growth and photosynthesis of these plants. Besides air, the ground humidity also regulates the development of plants. The air humidity is interconnected with the transpiration, while the ground humidity is linked to water absorption and the photosynthesis. An atmosphere with tremendous humidity decreases plants transpiration, thereby reducing growth and may endorse the proliferation of fungus. On the other hand, crouch humidity level environments might cause dehydration.

Radiation: Radiation is an elementary element in greenhouse production and sunlight is the key starting place of radiation. It is an imperative component for photosynthesis and carbon fixing. Momentous radiation features are intensity and duration. The radiation intensity is linked to plant development and the duration is explicitly associated with its metabolism.

CO_2 Concentration:CO_2 is an indispensable nutrient for the plant development, allowing the adaptation of carbon. The carbon retaining process occurs through the photosynthesis when plants take away CO_2 from the atmosphere. During photosynthesis, the plant use carbon and radiation to produce carbohydrate, whose purpose is to permit the plant development. Therefore, an enriched air environment should add to plant growth, but it is also vital to note that an intense carbon level may turn the environment poisonous.

4.3 THE DRIP IRRIGATION AUTOMATION SYSTEM

Conventional irrigation methods like overhead sprinklers and flood-type feeding systems usually leads to wetness in and around the lower portion of the leaves and stems of the plants. The entire soil surface becomes saturated and often stays wet even after the irrigation is completed. Such conditions induces infections in leaf mould with fungus growth. Flood-type methods consume a large volume of water, but the area between crops remains dry and receives moisture only by the incidental rainfall. The drip irrigation technique slowly applies some small amount of water to the plant's root zone. Water is supplied frequently, or on daily basis to maintain favourable soil moisture condition and prevents moisture-stress in the plant with proper use of water resources. WSN based drip irrigation system is a real time feedback control system which continuously monitors and controls all the activities of the drip irrigation system. A typical drip irrigation system consist of delivery systems, filters, pressure regulators, valve or gauges, chemical injectors, measuring sensors/instruments and controllers. WSN framework installed in the field could gather various physical and chemical parameters related to irrigation and plant health. The data is sent to the central server wirelessly through the motes and gateways. Based on the data received, the central server generates necessary control signals, which are routed to the respective controllers through control buses which enables implementation of closed-loop automation for the drip irrigation system. The main function of the system is to enable switching on and off of the motors and gauges remotely. The system also ensures that all the devices are checked for fault and only then the motor is started.

4.4 ALGORITHM FOR DRIP IRRIGATION SYSTEM

In this module, a mesh topology in which sensor nodes are placed in the farm area have been properly reviewed and adopted. Sensors in this topology are mobile whereas the base station is stationary and it collects the data from sensor nodes and process them. Efficient clustering of sensors in the wireless sensor field is considered as the basic operation in this research work. This work elaborates how to forward the sensed data to the base station effectively. For this purpose the farm area consisting of deployed WSN nodes has been formed initially. Now set the position of sensor and sink nodes in the farm and the monitoring station location. Set the transmission range for each node.

Now for each node, calculate distance from: node to node, node to sink and node to forwarding node. Also calculate: Angle a and predict min angle for next route based on fuzzy time series, if the current angle a is available as predicted, continue with path [find possible node (x,y)] or else hold packet for limited time. If connections (i,j) = 1 i.e., there is a link based on transmission range, send the packet information i.e., water level information and some other essential details about field of interest. The packet reaches to the sink node and gets stored there. Else connections (i, j) = infinity, end the structure. Therefore values of sensor nodes are stored in sink nodes. These sink node sends the stored values to monitoring station. On the basis of water level information, the switch is made on/off

4.5 RESULTS AND DISCUSSIONS

Here we obtain information of water level by using wireless sensor nodes. On the x-axis, we plot the number of readings of one sensor whereas on the y-axis we plot the magnitude of water level (figure 4.3). Here we have taken the ten water level readings of one sensor and the corresponding magnitude of water level readings. The next step is to deliver the obtained water level information to the forwarding node and then to the sink node (base station).

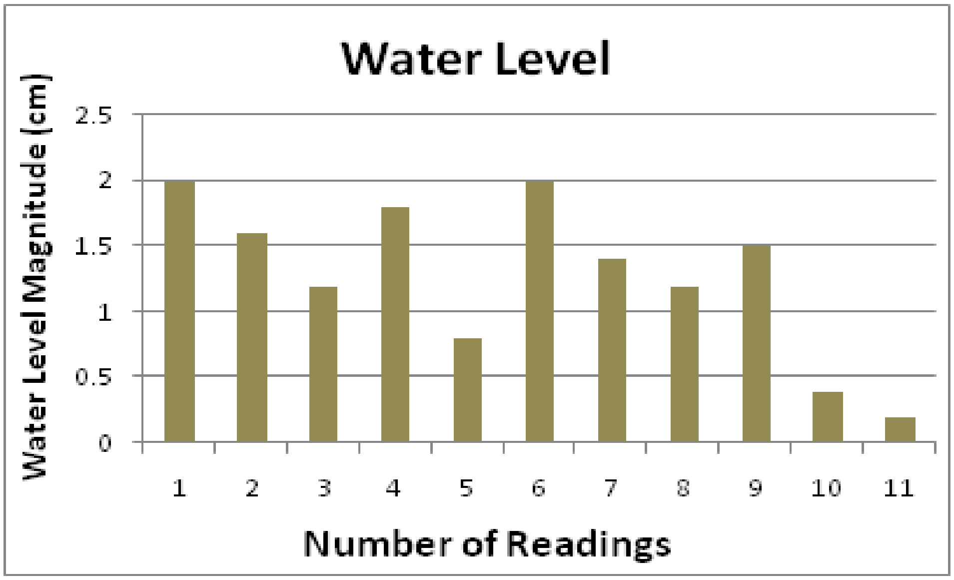

Figure 4.3: Water Level Information

The greater value of packet delivery ratio means the better performance of the protocol. The PDR is inversely proportional to Packet Lost Ratio (PLR) as expressed in equation 2. Packet lost ratio is the total number of packets dropped during the transmission.

4.6 SIMULATION RESULTS

By using fuzzy time series algorithm, we get the initial throughput of 46 bits/sec, which is represented by blue line (figure 4.4). It is known as Fuzzy THR. When Nuppy algorithm is employed, we get the throughput between 48 bits/sec. This is referred to as Nuppy THR, represented by red lines. In this comparison, with 200 sensor nodes employed for throughput calculation, we can clearly see that, the throughput of fuzzy time series increases with increase in the number of wireless sensor nodes.

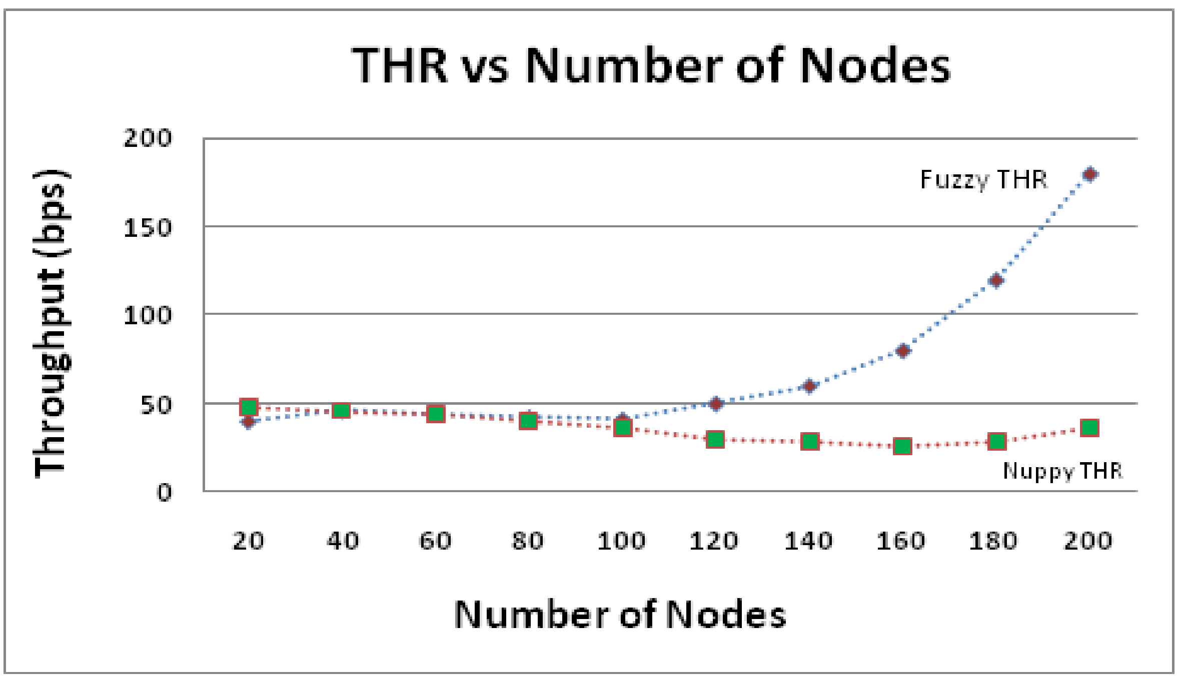

Figure 4.4: Throughput Vs number of nodes

Figure 4.5, shows the Nuppy delay being given by blue line, whereas fuzzy delay is represented by red line. In case of nuppy delay, the average end to end delay is found to be between 6.5 msec to 3 msec. In Fuzzy algorithm, the average end to end delay is found to occur between 3.8 msec to 1.8 msec. Hence by the employment of fuzzy time series algorithm, better average end to end delay could be attained which could be understood from the results. Hence, in improved Fuzzy based algorithm, reliable water level information could be attained in comparison with the Nuppy algorithm.

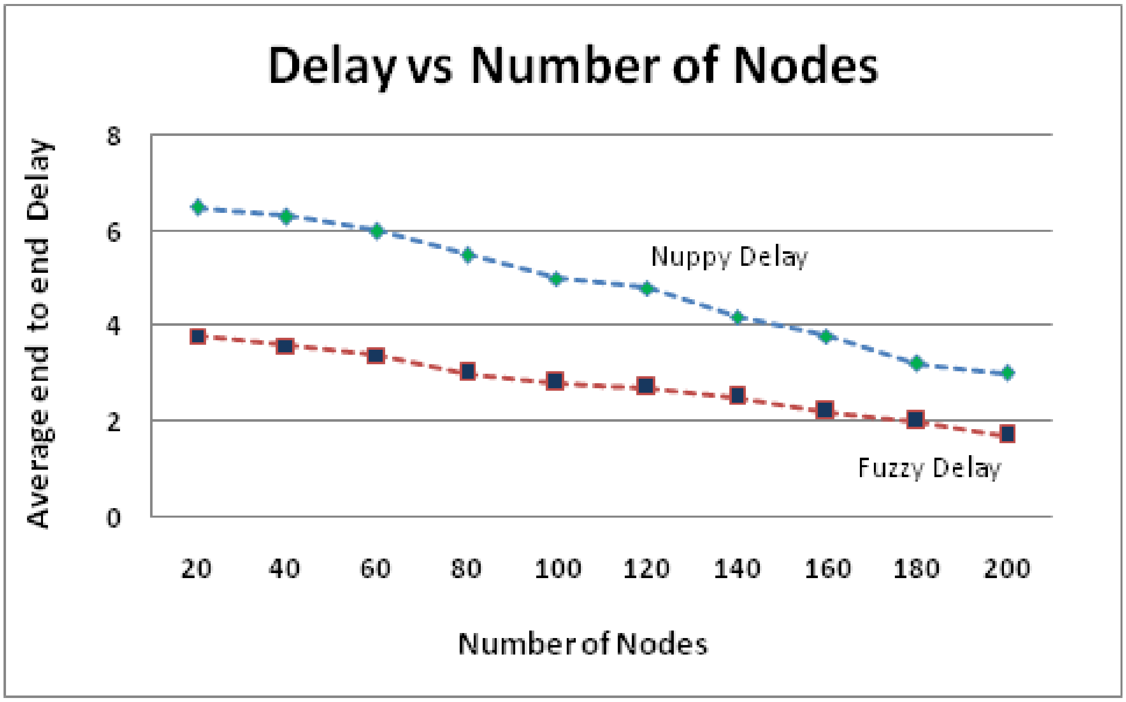

Figure 4.5: Average end to end delay versus number of nodes

Conventional Flood-type methods consume large volume of water, but the area between crop rows remains dry and receives moisture only from the incidental rainfall, whereas the drip irrigation technique slowly applies a small amount of water to the plant's root zone. Therefore by using the fuzzy based algorithm in wireless sensor drip irrigation technique, the wastage of water can be controlled. Also by using wireless sensor network, labourers are not essentially needed. In this module, water level information is achieved by the usage of 200 wireless sensor nodes. The comparison between the two clustering mechanisms, clearly gives an idea to employ fuzzy time series algorithm, when throughput is mandatory for a drip irrigation system. When the number of sensor nodes is increased, there is a large amount of power consumption by sensors to deliver the water/packet information to the monitoring station. Thus it is mandatory to minimize the power consumption by using some power control techniques. In future, an energy efficient protocol will be employed in the same mechanism, to maximize the network lifetime.

Module 5
HIERARCHICAL CLUSTERING METHODOLOGY

The advent of wireless electronics and sensing technologies has made the fabrication of low-cost wireless sensor nodes. A wireless sensor network (WSN) typically contains a large number of wireless sensor nodes. A wireless sensor node consists of low power processor, tiny memory, radio frequency module, various types of sensing devices and limited powered batteries. More amount of energy consumption in a WSN happens during wireless communications. The energy consumption when transmitting a single bit of data corresponds to thousands of cycles of CPU operations. These wireless sensor nodes assemble data from a sensing area which is possibly inaccessible for humans. Data gathered from the sensing field are usually reported to a remotely located base station (BS). This high redundancy of sensing power can greatly improve the sensing resolution and make sensor networks robust to swiftly changing environment. Some budding applications of wireless sensor networks are wildlife habit study, environmental observation and health care monitoring. Since wireless sensor nodes are power-constrained devices, long-haul transmissions should be kept to minimum in order to expand the network lifetime. Thus, direct communications between nodes and the base station are not intensely encouraged. An effective methodology to perk up efficiency is to arrange the network into several clusters (figure 5.1), with each cluster electing one node as its leader or cluster head (CH). A cluster head collects data from other sensor nodes in its cluster, directly or hopping through other nearby nodes. The data collected from nodes of the same cluster are extremely correlated. Data can be amalgamated during the data aggregation process. The fused data will then be transmitted to the base station directly or by multi-hop fashion. In such an arrangement, only cluster heads are required to transmit data over larger distances.

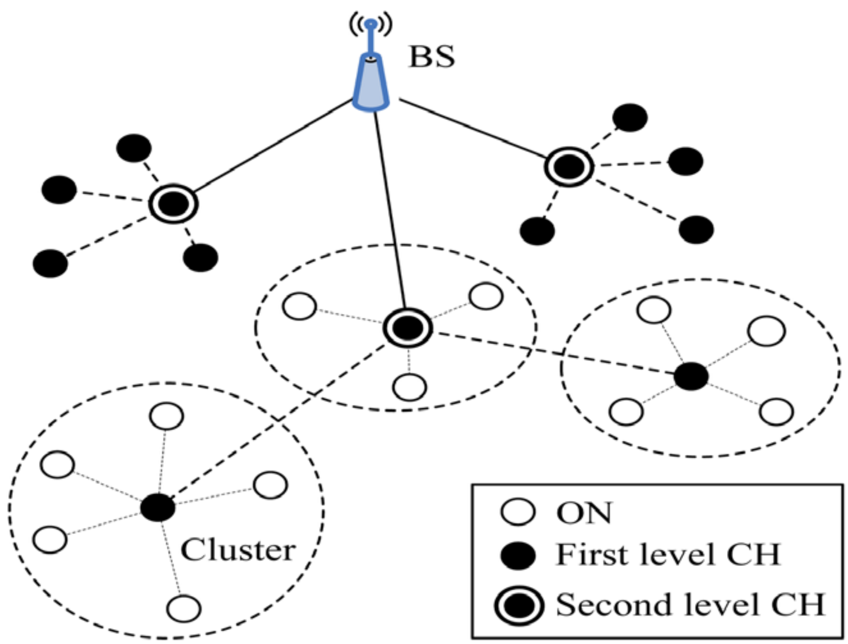

Figure 5.1: Clustering mechanism in a wireless sensor network

This module gives a profound description about energy efficient hierarchical distributed clustering algorithm. The remaining nodes will need to do only short-distance transmission. To distribute the workload of the cluster heads amidst the wireless sensor nodes, cluster heads will be re-elected from time to time. Clustering follows some projected advantages like localizing route setup within a particular cluster radius, efficient topology maintenance, energy efficiency, utilization of communication bandwidth efficiently and makes best use of network lifetime. Since clustering makes use of the mechanism of data aggregation, unnecessary communication between the sensor nodes, CH and BS is avoided. Energy consumption of wireless sensor nodes is greatly trimmed down and the overall network lifetime can thus be prolonged.

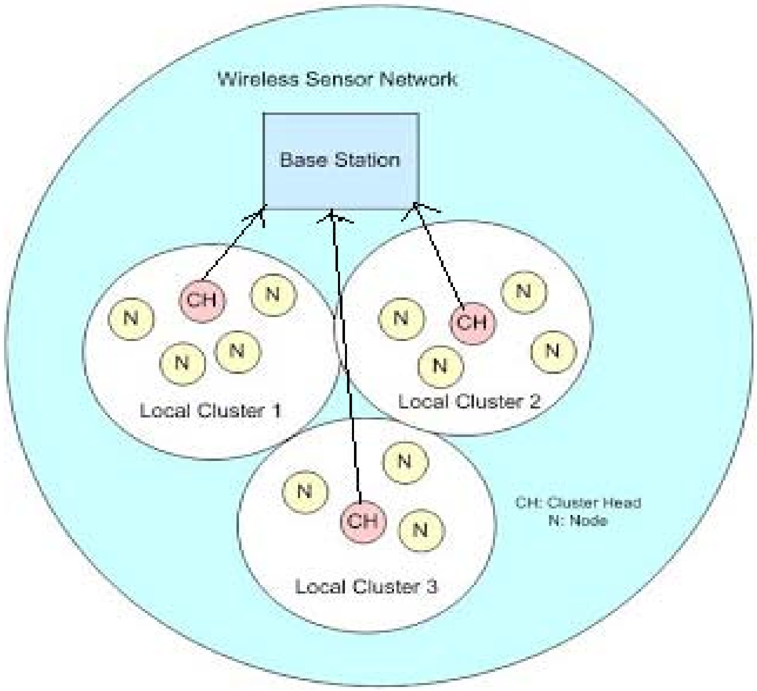

Figure 5.2: Evaluation of LEACH algorithm

Gone selecting itself as a CH, the node generally broadcasts an advertisement message which contains its own ID. The non-cluster head nodes can make a decision, which cluster to join according to the strength of the received advertisement signal. After the decision is made, every non-cluster head node must transmit a join- request message to the chosen cluster head to specify that it will be a member of the cluster. The cluster head produces and broadcasts the time division multiple-access (TDMA) schedule to swap the data with non-cluster sensor nodes without any collision after it receives all the join-request messages. The steady phase begins after the clusters are fashioned and the TDMA schedules are broadcasted. All the sensor nodes throw their data to the cluster head once per round during their allocated transmission slot based on the TDMA schedule and in other time, they turn off the radio in order to reduce energy consumption. However, the cluster heads must remain awake all the time. Therefore, it can receive every data from the nodes within their own clusters. On receiving all the data from the cluster, the cluster head perform data aggregation and onwards it to the base station directly. This is the complete process of steady phase. After a certain predefined time duration, the network will step into the next round. LEACH is the simplest clustering protocol which processes cluster approach and it can prolong the network lifetime when compared with multi-hop routing and static routing.

However, there are still some hiding drawbacks that should be considered. LEACH does not take into account the residual energy to select cluster heads and to construct clusters. As a result, nodes with lesser energy may be selected as cluster heads and then die much earlier. Moreover, since a node selects itself as a cluster head only according to the value of probability, it is tough to guarantee the number of cluster heads and their distribution. To overcome the inadequacy in LEACH, a hierarchical distributed clustering mechanism 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 cluster heads. These cluster heads send their data along with those received from lower level cluster heads to the next layer cluster heads. The cumulative process gets repeated and finally the data from all the layers reach the base station.

5.1 FEATURES OF THE PROPOSED SYSTEM

The initial step in the creation of LEACH (Low Energy Adaptive clustering of Hierarchy), is the creation of clusters. More specifically, each sensor nodes decides whether or not to turn into the cluster head for the current round. The decision is based on the priority and on the number to time the node has been a cluster head so for. The cluster nodes brings together the data and send them to the cluster head. The radio to each cluster nodes can be turned off when there is no sensing happens. When all the data have been received, the cluster head aggregates the data in to single composite signal. The composite signal is then sent to the base station directly.

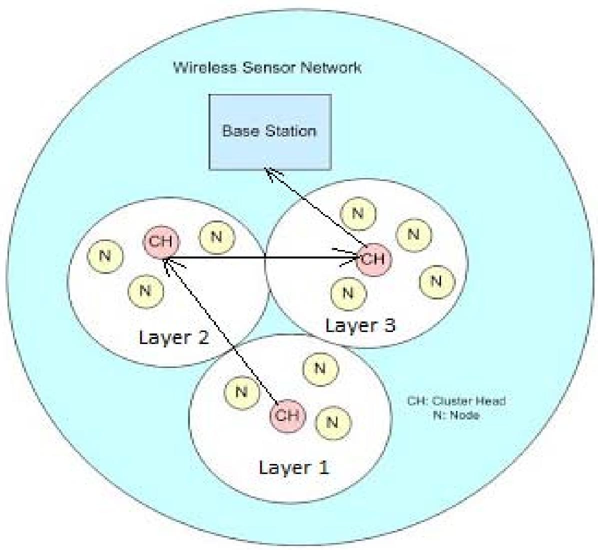

Figure 5.3: Evaluation of the proposed algorithm

LEACH protocol has the weakness, when periodic transmissions are unnecessary, thus causing pointless power consumption. The election of cluster head is based on priority, hence there is a possibility for weaker nodes to be drained because they are elected to be cluster heads as frequently as the stronger nodes. Moreover, the protocol is based on the assumptions that all nodes commence with the same amount of energy capacity in each election round and all the nodes can transmit with enough power to reach the base station if needed. Nevertheless, in many cases these assumptions are impractical. Also the base station should keep track on the sensor nodes in order to choose which node has the highest residual energy. Hence needless transmissions occur between the base station and cluster nodes, thereby causing increased power consumption.

The proposed work suggests a new idea over the existing techniques. In case of existing technique (figure 5.2), the aggregated data is sent to the base election directly by the CH, which leads to more energy usage. In the proposed algorithm the aggregated data is forwarded only to the next layer cluster head (figure 5.3), cutting down the communication distance between cluster head and the base station.

Two thresholds are employed namely hard threshold and soft threshold. Hard threshold is the bare minimum possible value, of an attribute to trigger a wireless sensor node to switch on its transmitter and transmit to the cluster head. Soft threshold is a little change in the value of the sensed attribute that triggers the node to switch on its transmitter and transmit data. The hard threshold tries to trim down the number of transmission by allowing their nodes to transmit only when the sensed attribute is beyond a critical value. In a similar way, the soft threshold further lessens the number of transmissions that might have otherwise occurred when there is little or no change in the sensed attribute. At each cluster change, the values of both the thresholds can be changed and thus enabling the user to control the trade-off between energy efficiency and data accuracy. This method reduces unwanted transmissions, trimming down the energy utilization.

The Set-up Phase: The main actions in the set-up phase are election of candidate nodes, selection of cluster heads, scheduling at each cluster and discovery of cluster head for CH-to-CH data transmission. During set-up phase, every node first decides whether or not it can become a candidate node in each region for the current round. This choice is based on the value of the threshold T(n) as used in LEACH protocol. As seen in equation 1, p should be given a large value in order to elect many candidate nodes. The cluster heads are elected among the candidate nodes. An advertisement message is used to elect cluster heads. For this, the candidate nodes employ a CSMA MAC protocol. Each candidate node broadcasts an advertisement message inside its transmission range and is dependent on the utmost distance between these levels.

In the proposed scheme, the advertisement range is given double of the maximum distance to cover other levels. When a candidate node is located within a × Advertisement Range where the value of a is predetermined between 0 and 1, it has to give up qualification of candidate node and has to end up joining the competition. An ordinary node, by contrast, decides the cluster to which it will belong for this round. This choice is based on the signal strength of the advertisement message. After each node has decided to which cluster it belongs, node must transmit its data to the suitable cluster head. After cluster head receives all the messages from the nodes that would like to be incorporated in the cluster and based on the number of nodes contained in the cluster, the cluster head creates a TDMA schedule and assigns each node a time slot when it can transmit.

Each cluster head broadcasts this same schedule back to the nodes in the cluster. After schedule creation, each cluster head performs cluster head discovery to discover an upward cluster head to reach the sink. For this, each cluster head uses two-way handshake technique, with REQ and ACK messages. Each cluster head broadcasts REQ message within the advertisement range. Upward cluster head on receiving this REQ message transmits ACK message back to the cluster head that had transmitted the REQ message.

The Steady-state Phase: The steady-state phase of the proposed scheme is analogous to other cluster-based protocols. Main activities of this phase are sensing and transmission of the sensed data. Each nodes senses and transmits the sensed data to its cluster head according to their own time schedule. When all the data has been received, the cluster head perform data aggregation in order to reduce the amount of data. Finally, each cluster head transmits data to the sink along the CH-to-CH routing path which have been fashioned during the set-up phase. After all the data is transmitted or a definite time is elapsed, the network goes back into the set-up phase again and the next round begins by electing the candidate nodes.

5.2 SIMULATION STUDY

Simulation Settings: All the simulations were carried using GloMoSim considering 15 sensor nodes. For the simulations, a network model similar to the one used in the conventional clustering protocols is assumed with the following properties.

Table 5.1: Simulation parameter setup

Parameter	Acronym	Values
Cluster topology (m)	C_t	100 x 100 m^2
Tx/Rx electronics constant	$E_{tx/rx}$	50nJ/bit
Amplifier constant	E_{amp}	10pJ/bit/m^2
CH energy threshold	E_{th}	10^{-4}J
Packet size	p	50 bytes
Number of nodes	N	15
Transmission range	R_{bc}	70m
Sensing range	R_{sense}	15m
Cluster range	$R_{cluster}$	30m

The sensor nodes are outfitted with power control capabilities. For the experiments, the network parameters and the communication energy parameters are set as shown in table 5.1. The deployment of wireless sensor nodes are shown in figure 5.4. Here the nodes are assumed to be static. The nodes organize into hierarchical group of clusters, short while after the deployment (figure 5.5). The cluster heads starts forwarding the aggregated data to the next higher layered cluster head immediately after hierarchical layers are formed. The process gets terminated for one round when all the aggregated data reaches the base station.

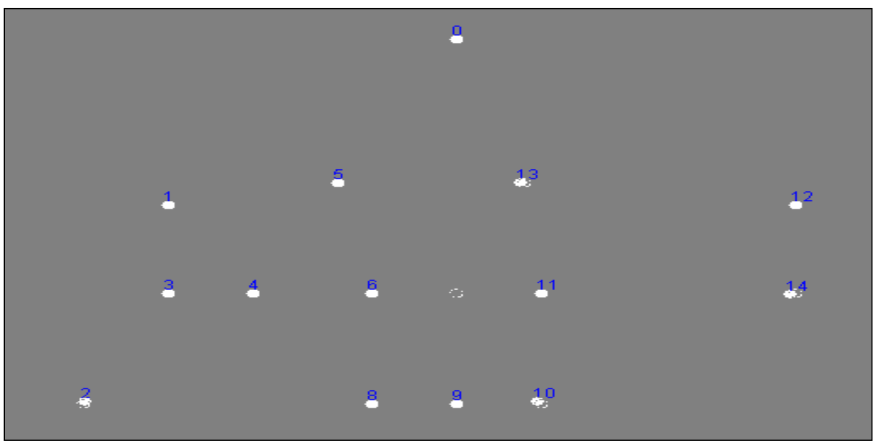

Figure 5.4: Nodes deployment in the proposed algorithm

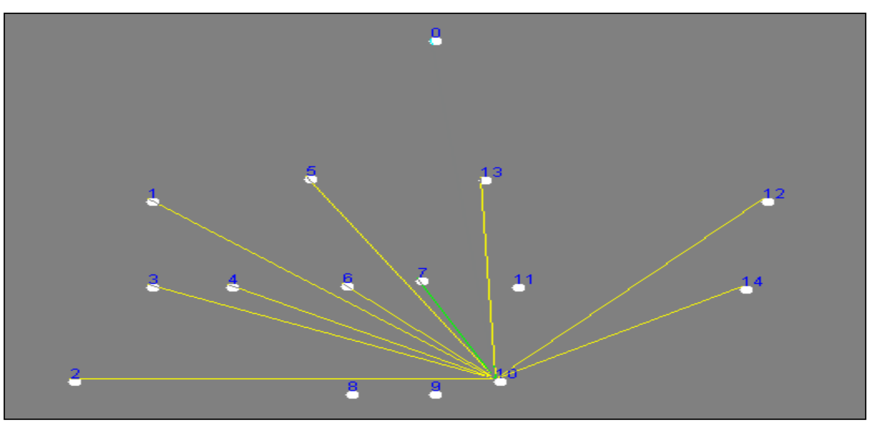

Figure 5.5: Cluster formation in the proposed algorithm

*Assumptions:*The radio channel is assumed to be symmetrical in manner. Thus, the energy required to transmit a message from a source to a destination node is same as the energy required to transmit the same message from the destination node back to the source node. Moreover, it is mainly assumed that the communication medium is contention free. Hence there is no need for retransmission of data. The initial energy of each node is assumed to be the identical.

5.3 SIMULATION RESULTS

The total system energy usage is the sum total of energy consumed during communication, processing, etc., which is the overall energy consumed for the complete clustering mechanism by the whole sensor network. As discussed in the previous section, LEACH algorithm uses more energy for communication between nodes and the cluster heads. It distributes the loading of cluster heads to all the nodes in the network by switch the cluster heads from time to time. Due to two-hop arrangement of the network, a node far from CH will have to consume more energy than a node nearer to the cluster head. This introduces a rough distribution of energy among the cluster members, affecting the total system energy. The uneven distribution of energy among the cluster members is avoided in the proposed algorithm by the usage of hierarchical clustering mechanism.

In the proposed algorithm, fewer communication energy is required which could be understood from the simulations. It uses the concept of threshold to further reduce the communication energy. From the simulation, it is also clear that the slope of LEACH algorithms is maximum, hence consuming the available energy easily compared to the proposed algorithm. Also in the proposed algorithm, parting among the layers is optimized to use optimum power for each layer. From figure 5.6, the system energy usage of the proposed algorithm is optimum for discrete number of rounds. But in case of LEACH, the energy usage is in a gradual manner. This positive performance of the proposed algorithm is mainly by the reduction in long-haul communications between the cluster head and base station.

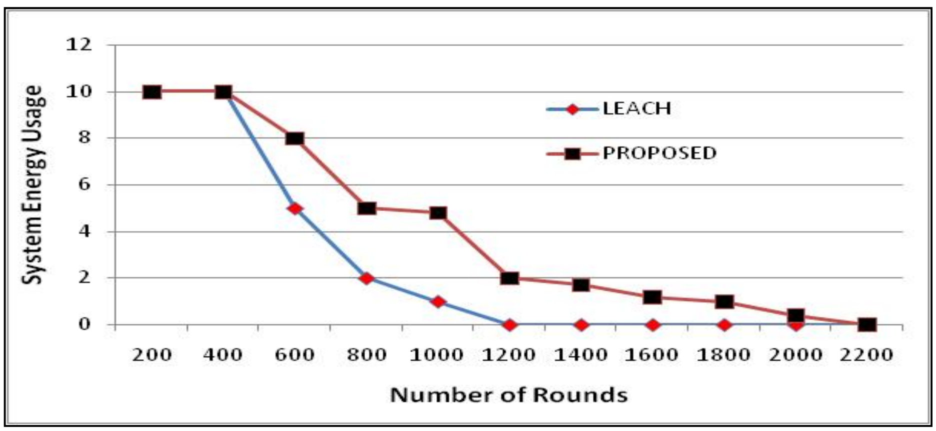

Figure 5.6: System energy usage versus number of rounds

The node death rate is the measure of the number of nodes die over a particular number of rounds, from the beginning of the process. When the data rate enlarges, the node death rate also increases equivalently. The networks formed by LEACH show periodical variations in data collection time. This is due to the selection function reliant on the number of data collection process. As the CH selection of LEACH is a function of the number of completed data collection processes, the number of cluster changes periodically. This raises up the node death rate. The proposed algorithm uses a restricted data collection process, as the concept of hierarchical clustering is employed. Also the proposed algorithm has an excellent control over the number of connections between the cluster nodes, cluster heads and base station. In LEACH, there is no control over the number of connections, which increases the data collection time, thereby increasing the data rate and node death rate. From figure 5.7, all the nodes die early in 3000 rounds for LEACH algorithm. The proposed algorithm shows prolonged performance, as all the nodes die only in 4500 rounds. Hence, the proposed algorithm shows excellent reduction in the node death rate compared to LEACH. This is mainly by the usage of soft threshold and hard threshold concept to reduce the redundant aggregated data transmission from cluster head to the base station.

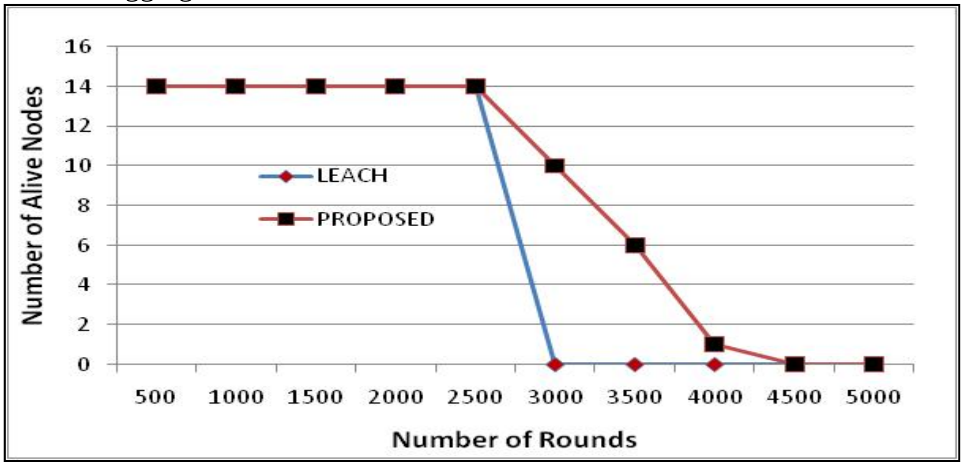

Figure 5.7: Node death rate versus number of rounds

This module is concerned with the introduction of hierarchical clustering mechanism in wireless sensor networks with the inclusion of threshold concept within the cluster head. The main feature of this proposed algorithm compared to the existing clustering mechanism (LEACH), is that the entire aggregated data is transmitted by the cluster head to the base station by forwarding through next higher layer cluster heads. Also soft threshold and hard threshold concepts are employed to further reduce the number of transmission from cluster head to the base station. Hence energy wastage by long distance transmission is avoided, thereby reducing energy utilization to much extent. The node death rate is reduced to a greater extent compared to the existing LEACH algorithm.

FUTURE DIRECTIONS

As a future direction, these proposed clustering algorithms shall be incorporated with some real-world applications like building automation, enemy tracking in military, forest fire detection and environmental monitoring. Distributed clustering algorithms based on biologically inspired social insect colonies shall be developed. This work shall be extended towards wireless sensor actuator network, where some control actions could be taken on the basis of the sensed phenomenon, which could become a door-opening scheme for agricultural applications. More distributed clustering algorithms shall be developed for mobile wireless sensor network. Future works may also concentrate on the improvement of other parameters like routing, sleep-awake scheduling, delay-minimization and quality-of-service. The simulation works in this thesis have been carried out only using the network simulator (NS-2), but in future the simulation works shall be carried out using other available simulation tools like JSIM, REAL, OPNET and NETSIM. The modified versions of the distributed clustering algorithms contained in this thesis could be formulated for heterogeneous wireless sensor network. As a future work, the output from the sensors will be incorporated with the internet with IP connectivity for global monitoring. A methodology that reduces sensor network failure shall be developed which will be viable for harsh environmental applications. A distributed clustering methodology shall be developed for static and mobile wireless sensor network with excellent security. A distributed clustering methodology that reduces energy hole while clustering shall be investigated in future.

REFERENCES

Abdo, SM &Shanmukhaswamy, MN 2012, 'New algorithm for optimized cluster heads with failure detection and recovery to extend coverage of wireless sensor network', International Journal of Scientific and Research Publications, vol. 2, no. 11, pp. 01-04.

Akyildiz, I, Su, W, Sankarasubramaniam, Y &Cayirci, E 2002, 'A survey on sensor networks', IEEE Communications Magazine, vol. 40, no. 8, pp. 102-114.

Alain, BB & John, FM 2010, 'An energy-efficient clique-based geocast algorithm for dense sensor networks', Communications and Network, vol. 2, no. 2, pp. 125-133.

Ali, M, Voigt, T &ZA 2006, 'Mobility management in sensor networks', Proceedings of the 2nd International Conference on Distributed Computing in Sensor Systems, pp. 131-140.

Amandeep, K &Rupinder, KG 2014, 'Event driven clustering scheme and energy efficient routing for wireless sensor network - a review', International Journal of Computer Science and Information Technologies, vol. 5, no. 4, pp. 4949-4951.

Anastasi, G, Conti, M, Monaldi, E &Passarella, A 2007, 'An adaptive data-transfer protocol for sensor networks with data mules', Proceedings of the IEEE International Symposium on World of Wireless, Mobile and Multimedia Networks, pp. 01-08.

Arampatzis, T, Lygeros, J &Manesis, S 2005, 'A survey of applications of wireless sensors and wireless sensor networks', Proceedings of the Mediterranean Conference on Control and Automation, pp. 719-724.

Arash, GD, Somayeh, S, Nafiseh, M &Javad, A 2012, 'SLGC: A new cluster routing algorithm in wireless sensor network for decrease energy consumption', International Journal of Computer Science Engineering and Applications, vol. 2, no. 3, pp. 39-51.

Bajaber, F &Awan, I 2009, 'Centralized dynamic clustering for wireless sensor networks', Proceedings of the International Conference on Advanced Information Networking and Applications, pp. 193-198.

Bandyopadhay, S & Coyle, E 2003, 'An energy-efficient hierarchical clustering algorithm for wireless sensor networks', Proceedings of the 22nd Annual Joint Conference of the IEEE Computer and Communications Societies, pp. 1713-1723.

Banerjee, S &Khuller, S 2001, 'A clustering scheme for hierarchical control in multi-hop wireless networks', Proceedings of 20th Joint Conference of the IEEE Computer and Communications Societies, pp. 1028-1037.

Banerjee, T, Xie, B, Jun, JH &Agrawal, DP 2007, 'LIMOC: Enhancing the lifetime of a sensor network with mobile cluster-heads', Proceedings of the IEEE Vehicular Technology Conference, pp. 133-137.

Baranidharan, B &Shanthi, B 2010, 'A survey on energy efficient protocols for wireless sensor networks', International Journal of Computer Applications, vol. 11, no. 10, pp. 0975-8887.

Barker, DJ, Ephremides, A &Flynn, JA 1984, 'The design and simulation of a mobile radio network with distributed control', IEEE Journal on Selected Areas in Communications, vol. 2, no. 1, pp. 226-237.

Bianchi, G 2000, 'Performance analysis of the IEEE 802.11 distributed coordination function', IEEE Journal on Selected Areas in Communications, vol. 18, no. 3, pp. 535-547.

Boselin Prabhu S. R. and Gajendran E., "Military Applications of Wireless Sensor Network System", Scientific Digest-A Multidisciplinary Journal of Scientific Research & Education, December-2016, Volume: 2, Issue: 12, pp. 164-168.

Boselin Prabhu S. R., N.Balakumar and A.Johnson Antony, "A Novel LEACH Based Protocol for Distributed Wireless Sensor Network", International Journal of Innovative Research in Technology, Volume 3, Issue 8, January 2017.

Boselin Prabhu S. R., N.Balakumar and A.Johnson Antony, "Wireless Sensor Network Based Smart Environment Applications", International Journal of Innovative Research in Technology, Volume 3, Issue 8, January 2017.

Boselin Prabhu S. R. and Gajendran E., "A Novel Systematic Approach for Aiding the Incapacitated Individual", Scientific Digest-A Multidisciplinary Journal of Scientific Research & Education, December-2016, Volume: 2, Issue: 12, pp. 169-174.

Boselin Prabhu S. R. and Gajendran E., "Monitoring Climatic Conditions using Wireless Sensor Networks", Scientific Digest-A Multidisciplinary Journal of Scientific Research & Education, January-2017, Volume: 3, Issue: 1, pp. 179-184.

Boselin Prabhu S. R. and Gajendran E., "Enhanced Battlefield Surveillance Methodology using Wireless Sensor Network", Scientific Digest-A Multidisciplinary Journal of Scientific Research & Education, 3(1), January-2017, Volume: 3, Issue: 1, pp. 185-190.

Boselin Prabhu S. R., N.Balakumar and A.Johnson Antony, "An Illustration of Optic Sensors in Recent Research Domains", International Journal of Innovative Research in Technology, Volume 3, Issue 8, January 2017.

Boselin Prabhu S. R., N.Balakumar and A.Johnson Antony, "Management Strategies for Voice Based Communication towards Emerging Networks", International Journal of Innovative Research in Technology, Volume 3, Issue 8, January 2017.

Boselin Prabhu S. R., N.Balakumar and A.Johnson Antony, "Evolving Constraints in Military Applications using Wireless Sensor Networks", International Journal of Innovative Research in Computer Science & Technology, Volume 5, Issue-1, pp. 184-187, January 2017.

Boselin Prabhu S. R., N.Balakumar and A.Johnson Antony, "Human Assistance Mechanism using Real World Embedded Systems", International Journal of Innovative Research in Computer Science & Technology, Volume 5, Issue-1, pp. 188-193, January 2017.

Boselin Prabhu S. R., N.Balakumar and A.Johnson Antony, “A Research on Smart Transportation using Sensors and Embedded Systems”, International Journal of Innovative Research in Computer Science & Technology, Volume 5, Issue-1, pp. 198-202, January 2017.

Boselin Prabhu S. R., N.Balakumar and A.Johnson Antony, “Constraints over Greenhouse Detection using Wireless Sensor Networks”, International Journal of Innovative Research in Computer Science & Technology, Volume 5, Issue-1, pp. 203-208, January 2017.

Boselin Prabhu S. R. and Gajendran E., “Distributed Clustering Approach for Wireless Sensor Networks Based on Hybrid Concept”, International Journal of Recent Research and Applied Studies, Volume 4, Issue 1(11), January 2017.

Boselin Prabhu S. R. and Gajendran E., “Analysis of Large Scale Wireless Sensor Network for Energy Efficiency”, International Journal of Recent Research and Applied Studies, Volume 4, Issue 1(11), January 2017.

Boselin Prabhu S. R. and Gajendran E., “An Analysis of Smart Irrigation System using Wireless Sensor Network”, International Journal of Recent Research and Applied Studies, Volume 4, Issue 1(11), January 2017.

Boselin Prabhu S. R. and Gajendran E., “Parametric Analysis of Varying Greenhouse Gases using Wireless Sensor Network”, International Journal of Recent Research and Applied Studies, Volume 4, Issue 1(11), January 2017.

Boselin Prabhu S. R. and Gajendran E., “Systematic Analysis of Congestion Control in WDM Mesh Networks”, International Journal of Advanced Research in Science, Engineering and Technology, Vol. 4, Issue 1, January 2017.

Boselin Prabhu S. R. and Gajendran E., “Mitigation of Research Insights in Wireless Electricity Transmission System”, International Journal of Advanced Research in Science, Engineering and Technology, Vol. 4, Issue 1, January 2017.

Boselin Prabhu S. R. and Gajendran E., “Design and Analysis of LTE Antenna for Fourth Generation Wireless System”, International Journal of Advanced Research in Science, Engineering and Technology, Vol. 4, Issue 1, January 2017.

Boselin Prabhu S. R. and Gajendran E., “Embedding Hierarchical Concept of Clustering for Large Scale Sensor Network”, International Journal of Advanced Research in Science, Engineering and Technology, Vol. 4, Issue 1, January 2017.

Boselin Prabhu S. R. and Gajendran E., “An Investigation on Enlightening Performance in an Overburdened Highway System by Integrating Roadside Technologies”, International Journal of Advances in Engineering Research (IJAER), Vol. No. 12, Issue No. V, November 2016, pp. 06-15.

Boselin Prabhu S. R. and Gajendran E., “Application of Robots for Smart Crop Cultivation in Rural Community Environments”, International Journal of Advances in Engineering Research (IJAER), Vol. No. 12, Issue No. V, November 2016, pp. 26-37.

Boselin Prabhu S. R. and Gajendran E., “An Investigation on Monitoring Cardiac Activities Using Microcontroller”, International Journal of Advances in Engineering Research (IJAER), Vol. No. 12, Issue No. V, November 2016, pp. 16-25.

Boselin Prabhu S. R. and Gajendran E., “An Investigation on Future Wireless Communication Technologies and Applications”, International Journal of Advances in Engineering Research (IJAER), Vol. No. 12, Issue No. VI, December 2016, pp. 01-08.

Boselin Prabhu S. R. and Gajendran E., “Novel Methodologies to Prevent Loss of Human Life in Battlefield Using Sensors”, International Journal of Advances in Engineering Research (IJAER), Vol. No. 12, Issue No. VI, December 2016, pp. 09-18.

Boselin Prabhu S. R. and Gajendran E., “Developments of Clustering Hierarchy for Wireless Sensor Networks”, International Journal of Current Engineering and Scientific Research, Vol. No. 04, Issue No. 01, 2017, pp. 28-32.

Boselin Prabhu S. R. and Gajendran E., “Integrating the Concept of Ant Based Clustering for Dense WSN Fields”, International Journal of Current Engineering and Scientific Research, Vol. No. 04, Issue No. 01, 2017, pp. 33-39.

Boselin Prabhu S. R. and Gajendran E., “Evaluation and Rectification of Security Issues in Embedded Systems”, International Journal of Current Engineering and Scientific Research, Vol. No. 04, Issue No. 01, 2017, pp. 40-46.

Boselin Prabhu S. R. and Gajendran E., “Highly Competent Clustering Mechanism for Connecting Wireless Sensor Network Fields”, International Journal of Inventions in Engineering & Science Technology, Vol. No. 02, January-December 2016.

Boselin Prabhu S. R. and Gajendran E., “Smart Oil Field Management Using Wireless Communication Techniques”, International Journal of Inventions in Engineering & Science Technology, Vol. No. 02, January-December 2016, pp. 100-107.

Boselin Prabhu S. R. and Gajendran E., “Monitoring Atmospheric Conditions Using Distributed Sensors”, International Journal of Inventions in Engineering & Science Technology, Vol. No. 02, January-December 2016, pp. 108-120.

Boselin Prabhu S. R. and Gajendran E., “An Investigation on Remote Controlled Tank Using Sensors for Defense Applications”, International Journal of Innovations in Scientific Engineering, Vol. No. 03, January-June 2016, pp. 44-51.

Boselin Prabhu S. R. and Gajendran E., “Self-Initializing Wireless Sensor Based Combat Surveillance System”, International Journal of Innovations in Scientific Engineering, Vol. No. 03, January-June 2016, pp. 52-60.

Boselin Prabhu S. R. and Gajendran E., “Integrating Modern Technologies for Wireless Charger for Mobile Phone Systems”, International Journal of Innovations in Scientific Engineering, Vol. No. 03, January-June 2016, pp. 61-68.

Boselin Prabhu S. R. and Gajendran E., “A Research on Robotic Application of Embedded Systems for Enhanced Security”, International Journal of Universal Science and Engineering, Vol. No. 02, January-December 2016, pp. 11-17.

Boselin Prabhu S. R. and Gajendran E., “An Investigation on Sensor Based Recognition System for Disabled”, International Journal of Universal Science and Engineering, Vol. No. 02, January-December 2016, pp. 18-29.

Boselin Prabhu S. R. and Gajendran E., “Contemporary Challenges in Environmental Monitoring Application of Wireless Sensors”, International Journal of Universal Science and Engineering, Vol. No. 02, January-December 2016, pp. 30-40.

Boselin Prabhu S. R. and Gajendran E., “An Analysis of Fiber Optic Sensors and Biosensors towards Real World Applications”, International Journal of Advanced Computing and Electronics Technology, Vol. No. 04, Issue 01, pp. 01-05, January 2017.

Boselin Prabhu S. R. and Gajendran E., “Certain Investigations of Distributed Clustering Schemes for Wireless Sensor Networks”, International Journal of Advanced Computing and Electronics Technology, Vol. No. 04, Issue 01, pp. 10-17, January 2017.

Boselin Prabhu S. R. and Gajendran E., “Prospective Applications of Wireless Sensor Node and Wireless Sensor Network”, International Journal of Advanced Computing and Electronics Technology, Vol. No. 04, Issue 01, pp. 18-26, January 2017.

Boselin Prabhu S. R. and Gajendran E., “A Novel Call Admission Control Methodology for Long-Term Evolution Networks”, International Journal of Advanced Computing and Electronics Technology, Vol. No. 04, Issue 01, pp. 41-45, January 2017.

Boselin Prabhu S. R. and Gajendran E., “An Investigation of Medical Applications of Integrated Sensor Networks”, International Journal of Advanced Computing and Electronics Technology, Vol. No. 04, Issue 01, pp. 46-50, January 2017.

Boselin Prabhu S. R. and Gajendran E., “Emerging Application Mechanisms of Optical Fiber Sensors”, International Journal of Environmental and Social Sustainability (IJESS), Vol. No. 02, pp. 18-21, March 2016 – February 2017.

Boselin Prabhu S. R. and Gajendran E., “Prolonging Lifetime in Wireless Sensor Networks using Enhanced Hierarchy”, International Journal of Environmental and Social Sustainability (IJESS), Vol. No. 02, pp. 22-28, March 2016 – February 2017.

Boselin Prabhu S. R. and Gajendran E., “Emerging Human Centric Domains of Wireless Sensor Network”, International Journal of Environmental and Social Sustainability (IJESS), Vol. No. 02, pp. 29-36, March 2016 – February 2017.

Boselin Prabhu S. R. and Gajendran E., “Technology to Avoid Accidents in Overburdened Highways”, International Journal for Technological Research in Engineering, Volume 4, Issue 5, pp. 721-725, January-2017.

Boselin Prabhu S. R. and Gajendran E., “Applications of Wireless Sensor Networks in Battlefield Surveillance”, International Journal for Technological Research in Engineering, Volume 4, Issue 5, pp. 742-746, January-2017.

Boselin Prabhu S. R. and Gajendran E., “Enduring Applications of Mobile Based Communication Systems”, International Journal for Technological Research in Engineering, Volume 4, Issue 5, pp. 737-741, January-2017.

Boselin Prabhu S. R. and Gajendran E., “Automation of Agricultural Fields Using Sensors and Microcontroller”, International Journal for Technological Research in Engineering, Volume 4, Issue 5, pp. 731-736, January-2017.

Boselin Prabhu S. R. and Gajendran E., “Monitoring Health Issues Using Embedded Systems”, International Journal for Technological Research in Engineering, Volume 4, Issue 5, pp. 726-730, January-2017.

Boselin Prabhu S.R. and Sophia S., “Distributed Clustering Mechanism in Dense Wireless Sensor Network”, Research Journal of Engineering and Technology, 7(1), pp. 19-23, October 2016.

Boselin Prabhu S. R. and Balakumar N., “Methodology for Improving Security Issues and Reducing Vulnerability in Microprocessors”, International Journal of Advances in Agricultural Science and Technology, Vol.3, Issue.6, November- 2016, pp. 60-65.

Boselin Prabhu S. R. and Balakumar N., “Smart Antenna and RFID Technology Enabled Wireless Charger for Mobile Phone Batteries”, International Journal of Current Engineering and Scientific Research, Vol. 3, Issue. 12, December 2016, pp. 66-70.

Boselin Prabhu S. R., “Editor’s Note”, Journal of Electrical and Electronic Systems (JEES), Volume 5, Issue 3, December 2016, pp. 01-02.

Boselin Prabhu S. R. and Balakumar N., “Methodology for Improving Security Issues and Reducing Vulnerability in Microprocessors International Journal of Advances in Agricultural Science and Technology, Vol. 3, No. 6, November 2016, pp. 60-65.

Boselin Prabhu S. R. and Balakumar N., “Research Insights in Clustering for Sparsely Distributed Wireless Sensor Network”, International Journal of Advances in Engineering Research (IJAER), Vol. No. 12, Issue No. IV, October 2016, pp. 13-24.

Boselin Prabhu S. R. and Balakumar N., “Highly Scalable Energy Efficient Clustering Methodology for Sensor Networks”, International Journal of Advances in Engineering Research (IJAER), Vol. No. 12, Issue No. IV, October 2016, pp. 01-12.

Boselin Prabhu S. R. and Balakumar N., “Functionalities and Recent Real World Applications of Biosensors”, International Journal of Computer Science & Communication Networks, Vol 6 Issue 5, pp. 211-216.

Boselin Prabhu S. R. and Balakumar N., “A Research on Efficient Processor Design Structure with Reduced Memory Gap”, International Journal of Research in Electronics and Computer Engineering, Vol. 4, Issue 4, Oct-Dec 2016, pp. 158-164.

Boselin Prabhu S.R., Rajeswari P. and Dinesh Kumar A., “An Analytical Review of Fiber-Optic Sensors and Biosensors, Journal of Engineering, Scientific Research and Applications, Volume 2, Issue 1, 2016, pp. 58-61.

Boselin Prabhu S.R., Balakumar N., Rajeswari P. and Dinesh Kumar A., “Wireless Electricity Transfer Methodologies Using Embedded System Technology”, Journal of Engineering, Scientific Research and Applications, Volume 2, Issue 1, 2016, pp. 81-89.

Boselin Prabhu S.R., Rajeswari P. and Dinesh Kumar A., "Analysis of Decentralized Clustering Hierarchy for Highly Distributed WSN", Journal of Engineering, Scientific Research and Applications, Volume 2, Issue 1, 2016, pp. 45-49.

Boselin Prabhu S. R., "Reliable Security Approach for Wireless Embedded Systems", International Journal of Emerging Technology and Innovative Engineering, Vol. 2, Issue 11, November 2016, pp. 402-406.

Boselin Prabhu S. R., "An Elaborative Literature of Hierarchical Clustering Methodologies for Dense WSNs", SK International Journal of Multidisciplinary Research Hub, Volume 3, Issue 11, November 2016, pp. 15-19.

Boselin Prabhu S. R., and Pradeep M., "An Experimental Analysis of Metal Detecting Spy Robot and Its Application", International Journal of Research in Electronics, Volume 3, Issue 3, 2016, pp. 52-54.

Boselin Prabhu S. R., and Pradeep M., "Implementation of Voice Recognition Wireless Home Automation System with Zigbee", International Journal of Research in Electrical Engineering, Vol. 3, Issue 4, December 2016, pp. 54-58.

Boselin Prabhu S. R., and Pradeep M., "A Reservation Based Call Admission Control in LTE Networks", International Journal of Research in Computer Science, Volume 3, Issue 1, 2016, pp. 68-71.

Boselin Prabhu S. R., and Pradeep M., "A Novel Approach to Attain Enhanced Security in Medical Sensor Networks", International Journal of Modern Trends in Engineering and Science, Volume 3, Issue 12, December 2016, pp. 84-87.

Boselin Prabhu S. R., "Zone-Based Clustering Approach for Separated Wireless Sensor Network Fields", Journal of Electrical & Electronic Systems, Volume 5, Issue 4, pp. 1-3, 2016. (Editorial Note)

Boselin Prabhu S. R. and Balakumar N., "Enhanced Clustering Methodology for Lifetime Maximization in Dense WSN Fields", International Journal for Technological Research in Engineering, Volume 4, Issue 2, pp.343-348, October-2016

Boselin Prabhu S. R. and Balakumar N., "Suggested Mechanisms for the Employment of MPPT Principle Over a Photovoltaic Module", International Journal of Research in Electrical Engineering, Volume 3, Issue 3, pp. 45-49, October 2016.

Boselin Prabhu S. R. and Balakumar N., "A Research on Various Maximum Power Point Tracking Algorithms in a Photovoltaic System", South Asian Journal of Engineering and Technology, Volume 2, Number 28, 1-8.

Boselin Prabhu S. R. and Balakumar N., "Highly Distributed and Energy Efficient Clustering Algorithm for Wireless Sensor Networks", International Journal of Research – Granthaalayah, Volume 4, Number 9, September 2016.

Boselin Prabhu S. R. and Balakumar N., "Evaluation of Quality in Network and Interoperable Connectivity between IP Networks", International Journal of Current Engineering and Scientific Research, Volume 3, Issue 9, pp. 81-85.

Boselin Prabhu S. R. and Balakumar N., "Performance Evaluation and Implementation of Hybrid Cascaded Energy Efficient Kogge Stone Adder", ASTM JOTE Journal (Under Review).

Boselin Prabhu S. R. and Balakumar N., "Enhanced Zone-Based Clustering Method for Energy Efficient Wireless Sensor Network", ARC International Journal of Innovative Research in Electronics and Communications, Volume 3, Issue 4, pp. 01-06, 2016.

Boselin Prabhu S. R. and Balakumar N., "Real-World Wireless Power Transmission under Various Scenarios and Considerations", International Journal of Innovative and Applied Research, Volume 4, Issue 7, pp. 24-29.

Boselin Prabhu S. R., Balakumar N. and Sophia S., "Biologically Inspired Clustering Mechanism in Dense Distributed Wireless Sensor Networks", International Journal of Engineering Studies and Technical Approach, Volume 2, Number 7, July 2016.

Boselin Prabhu S. R. and Balakumar N., "Performance Evaluation of Maximum Power Point Tracking Principle for PV Systems", International Journal of Research in Electronics & Communication Technology, Volume 3, Issue 3, pp. 21-24, 2016.

Boselin Prabhu S.R. and Sophia S., "Bio-Medical Application of Wireless Power Transmission System", International Journal of Research and Engineering, Volume 3, Number 7, July 2016.

Boselin Prabhu S.R. and Sophia S., "Comparative Assessment of Various Generations in Narrowband Networking", International Journal of Multidisciplinary Research and Modern Education, June 2016.

Boselin Prabhu S.R. and Sophia S., "The study of Low Energy Adaptive Clustering Hierarchy and further developments", The Research Journal, 2(3), May-June 2016.

Boselin Prabhu S.R. and Sophia S., "Dense Distributed Wireless Sensor Networks using Jumping Ants", International Journal of Computer Science Research, Volume 4, Number 1, June 2016.

Boselin Prabhu S.R. and Sophia S., "Energy Efficient Adder for Digital Signal Processing Architecture", International Journal of Computer Science Research, Volume 4, Number 1, June 2016.

Boselin Prabhu S.R. and Sophia S., "The Impact of Distributed Clustering Mechanism in Dense WSN", Research Journal of Science and Technology, Volume 7, Number 1, June 2016.

Boselin Prabhu S.R. and Sophia S., "Cluster Initialization in Dense Distributed Wireless Sensor Networks using Jumping Ants", The Research Journal, 2(3), May-June 2016.

Boselin Prabhu S.R., "Evaluation of Wireless Solar Power Transmission through Satellite (SPS)", The Research Journal, 2(2), March-April 2016.

Boselin Prabhu S.R. and Sophia S., "Literature and comparative survey of future wireless communication", Galaxy: International Multidisciplinary Research Journal, 4(1), January 2016.

Boselin Prabhu S.R. and Dhakshinamoorthi P., "Nodes routing mechanism for MANET in adversarial environment", International Journal of Emerging Technology and Innovative Engineering, 2(1), January 2016.

Boselin Prabhu S.R., Senthil Kumar T., Rajkumar R. and Sophia S., "A methodology for reducing energy utilization in dense wireless sensor networks", International Journal of Research –Granthaalayah, 4(1), January 2016.

Boselin Prabhu S.R., Senthil Kumar T., Rajkumar R. and Sophia S., "The Impact of Clustering Mechanism in Dense Wireless Sensor Network", Scholars Journal of Engineering and Technology, 4(1), 4(1), January 2016.

Boselin Prabhu S.R. and Sophia S., "Issues in environmental pollution monitoring using distributed wireless sensor network", Pollution Research Journal, 34(1), 2015.

Boselin Prabhu S.R. and Sophia S., "Distributed clustering using enhanced hierarchical methodology for dense WSN fields", International Journal of Applied Engineering Research, 10(6), 2015.

Boselin Prabhu S.R. and Sophia S., "Cluster integrated self-forming wireless sensor based system for intrusion detection and perimeter defence applications", International Journal of Computer Science and Business Informatics, 15(3), 2015.

Boselin Prabhu S.R., Inigo Mathew A., Rajkumar M., RajkumarRamanujam and Sophia S., "Proposed method to save the soldiers inside the main battle tank via high bandwidth links-remote controlled tank, American Journal of Computer Science and Engineering Survey, 3(6), 2015.

Boselin Prabhu S.R., Inigo Mathew A., Rajkumar M., RajkumarRamanujam and Sophia S., "Passive method to detect and locate the fault in high tension power lines – line break", International Journal of Computer Science and Mobile Computing, 4(12), 2015.

Boselin Prabhu S.R. and Rajkumar R., "Effective clustering mechanism when both the sensor nodes and base station are mobile", ARPN Journal of Engineering and Applied Sciences, 11 (5), March 2016.

Boselin Prabhu S.R. and Rajkumar R., "Traffic decongestion in toll plaza using electronic toll collection", Australian Journal of Basic and Applied Sciences, 9(35), January 2016.

Boselin Prabhu S.R. and Dhakshinamoorthi P., "Power control and data log system design in loom industry using controller", American Journal of Computer Science and Engineering Survey, 3(1), 2015.

Boselin Prabhu S.R. and Sophia S., "Self-forming WSN based system for intrusion detection", International Journal of Electrical and Electronics Research, 3(2), 2015.

Boselin Prabhu S.R. and Sophia S., ‘Evaluation of clustering parameters in WSN fields using distributed zone-based approach’, ASTM Journal of Testing and Evaluation, 43(6), 2015.

Boselin Prabhu S.R. and Sophia S., “Environmental monitoring and greenhouse control by distributed sensor Network”, International Journal of Advanced Networking and Applications, 5(5), 2014.

Boselin Prabhu S.R. and Sophia S., “Greenhouse control using wireless sensor network”, Scholars Journal of Engineering and Technology, 2(4), 2014.

Boselin Prabhu S.R. and Sophia S., ‘Modern cluster integration of advanced weapon system and wireless sensor based combat system’, Scholars Journal of Engineering and Technology, 2(6A), 2014.

Boselin Prabhu S.R. and Sophia S., ‘A review of efficient information delivery and clustering for drip irrigation management using WSN’, International Journal of Computer Science and Business Informatics, 14(3), 2014.

Boselin Prabhu S.R. and Sophia S., ‘Mobility assisted dynamic routing for mobile wireless sensor networks’, International Journal of Advanced Information Technology, 3(3), 2013.

Boselin Prabhu S.R. and Sophia S., ‘A review of energy efficient clustering algorithm for connecting wireless sensor network fields’, International Journal of Engineering Research and Technology, 2(4), 2013.

Boselin Prabhu S.R. and Sophia S., ‘Variable power energy efficient clustering for wireless sensor networks’, Australian Journal of Basic and Applied Sciences, 7(7), 2013.

Boselin Prabhu S.R. and Sophia S., ‘Capacity based clustering model for dense wireless sensor networks’, International Journal of Computer Science and Business Informatics, 5(1), 2013.

Boselin Prabhu S.R. and Sophia S., ‘Hierarchical distributed clustering algorithm for energy efficient wireless sensor networks’, International Journal of Research in Information Technology, 1(12), 2013.

Boselin Prabhu S.R. and Sophia S., ‘Real-world applications of distributed clustering mechanism in dense wireless sensor networks’, International Journal of Computing Communications and Networking, 2(4), 2013.

Boselin Prabhu S.R. and Sophia S., ‘An integrated distributed clustering algorithm for dense WSNs’, International Journal of Computer Science and Business Informatics, 8(1), 2013.

Boselin Prabhu S.R. and Sophia S., ‘A research on decentralized clustering algorithms for dense wireless sensor networks’, International Journal of Computer Applications, 57(20), 2012.

Boselin Prabhu S.R. and Sophia S., ‘A novel delay-tolerant and power-efficient technique in wireless sensor networks’, The Technology World Quarterly Journal, 3(3), 2012.

Boselin Prabhu S.R., Thirunavukarasu A. and Kaliappan S., “Improvement of quality of service in time sensitive wireless sensor networks”, International Journal of Wireless Communication, 3(1), 2011.

Chan, H, Luk, M &Perrig, A 2004, ‘ACE: An emergent algorithm for highly uniform cluster formation’, Proceedings of the 1st European Workshop on Wireless Sensor Networks, pp. 154-171.

Chang, JH &Tassiulas, L 2004, ‘Maximum lifetime routing in wireless sensor networks’, IEEE/ACM Transactions on Networking, vol. 12, no. 4, pp. 609-619.

Chen, J &Shen, H 2008, ‘MELEACH-L: more energy-efficient LEACH for large-scale WSNs’, Proceedings of the Wireless Communications Networking and Mobile Computing, pp. 01-04.

Cheng, CT, Tse, CK & Lau, FCM 2011, ‘A clustering algorithm for wireless sensor networks based on social insect colonies’, IEEE Sensors Journal, vol. 11, no. 3, pp. 711-721.

Chia, HT & Yu, CT 2012, ‘A path-connected-cluster wireless sensor network and its formation addressing and routing protocols’, IEEE Sensors Journal, vol. 12, no. 6, pp. 2135-2144.

Dantu, K, Rahimi, MH, Shah, H, Babel, S, Dhariwal, A &Sukhatme, GS 2005, ‘Robomote: enabling mobility in sensor networks’, Proceedings of the 4th IEEE International Symposium on Information Processing in Sensor Networks, pp. 404-409.

Demirbas, M, Arora, A & Mittal, V 2004, ‘FLOC: A fast local clustering service for wireless sensor networks’, Proceedings of Workshop on Dependability Issues in Wireless Ad-Hoc Networks and Sensor Networks.

Depedri, A, Zanella, A &Verdone, R 2003, ‘An energy efficient protocol for wireless sensor networks’, Proceedings of the Autonomous Intelligent Networks and Systems, pp. 01-06.

Devasena, A &Sowmya, B 2013, ‘A study of power and energy efficient clustering protocols in wireless sensor networks’, International Journal of Advance Research in Computer Science and Management Studies, vol. 1, no. 6, pp. 103-117.

Ding, P, Holliday, J &Celik, A 2005, ‘Distributed energy efficient hierarchical clustering for wireless sensor networks’, Proceedings of the IEEE International Conference on Distributed Computing in Sensor Systems, pp. 322-339.

Dionisis, K, Panagiotis, T, Anthony, T, Nikolaos, P &Dimitrios, DV 2008, ‘Hierarchical energy efficient routing in wireless sensor networks’, Proceedings of the 16th IEEE Mediterranean Conference on Control and Automation Congress Centre, pp. 1856-1861.

Doherty, L (eds.) 2005, Algorithms for Position and Data Recovery in Wireless Sensor Networks, UC Berkeley EECS Masters Report.

Do-Seong, K &Yeong-Jee, C 2006, ‘Self-organization routing protocol supporting mobile nodes for wireless sensor network’, Proceedings of the International Conference on Computational Sciences, pp. 622-626.

Ekici, E, Yaoyao, G &Bozdag, D 2006, ‘Mobility-based communication in wireless sensor networks’, IEEE Communications Magazine, vol. 44, no. 7, pp. 56-62.

Fan, X & Song, Y 2007, ‘Improvement on LEACH protocol of wireless sensor network’, Proceedings of the International Conference on Sensor Technologies and Applications, pp. 260-264.

Farooq, MO, Dogar, AB & Shah, GA 2010, ‘MR-LEACH: Multi-hop routing with low energy adaptive clustering hierarchy’, Proceedings of the 4th International Conference on Sensor Technologies and Applications, pp. 262-268.

Guang, FL &Taieb, Z 2007, ‘A ring-structured energy-efficient clustering architecture for robust communication in wireless sensor networks’, International Journal of Sensor Networks, vol. 2, no. 1/2, pp. 34-43.

Guo, L, Xie, Y, Yang, C & Jing, Z 2010, ‘Improvement on LEACH by combining adaptive cluster head election and two-hop transmission’, Proceedings of the 9th International Conference on Machine Learning and Cybernetics, pp. 11-14.

Haitao, Z, Shiwei, Z &Wenshao, B 2014, ‘A clustering routing protocol for energy balance of wireless sensor network based on simulated annealing and genetic algorithm’, International Journal of Hybrid Information Technology, vol. 7, no. 2, pp. 71-82.

Han, L 2010, ‘LEACH-HPR: An energy efficient routing algorithm for heterogeneous WSN’, Proceedings of the IEEE International Conference on Intelligent Computing and Intelligent Systems, pp. 507-511.

Heinzelman, WB, Chandrakasan, AP &Balakrishnan, H 2002, ‘Application specific protocol architecture for wireless microsensor networks’, IEEE Transactions on Wireless Communications, vol. 1, no. 4, pp. 660-670.

Hill, J 2000, ‘System architecture directions for networked sensors’, Proceedings of the 9th International Conference on Architectural Support for Programming Languages and Operating Systems, pp. 93-104.

Hossein, J 2013, ‘An introduction to various basic concepts of clustering techniques on wireless sensor networks’, International journal of Mobile Network Communications and Telematics, vol. 3, no. 1, pp. 01-17.

Huifang, C, Hiroshi, M, Yoshitsugu, O, Tomohiro, K & Tadanori, M 2007, ‘Adaptive data aggregation for clustered wireless sensor networks’, Proceedings of the Ubiquitous Intelligence and Computing, pp. 475-484.

Jaswant, SR, Neelesh, G &Neetu, S 2014, ‘Energy efficient data communication approach in wireless sensor networks’, International Journal of Advanced Smart Sensor Network Systems, vol. 4, no. 3, pp. 01-12.

Jeong, H, Nam, CS, Jeong, YS & Shin, DR 2008, ‘A mobile agent based LEACH in wireless sensor network’, Proceedings of the International Conference on Advanced Communication Technology, pp. 75-78.

Jerusha, S, Kulothungan, K &Kannan, A 2012, ‘Location aware cluster based routing in wireless sensor networks’, International Journal of Computer and Communication Technology, vol. 3, no. 5, pp. 01-06.

Ji, H 1997, Resource management in communication networks via economic models. Ph.D. thesis, Rutgers University, New Jersey.

Junping, H, Yuhui, J & Liang, D 2008, ‘A time-based cluster head selection algorithm for LEACH’, IEEE Symposium on Computers and Communications, pp. 1172-1178.

Karkvandi, H, Pecht, E &Yadid, O 2011, ‘Effective lifetime-aware routing in wireless sensor networks’, IEEE Sensors Journal, vol. 11, no. 12, pp. 3359-3367.

Krishnamachari, B, Estrin, D & Wicker, S 2002, ‘Modelling data-centric routing in wireless sensor networks’, Proceedings of the 21st Joint Conference of the IEEE Computer and Communications Societies, pp. 02-14.

Laibowitz, M &Paradiso, JA 2005, ‘Parasitic mobility for pervasive sensor networks’, Proceedings of the Conference on Pervasive Computing, pp. 255-278.

Li, CF, Ye, M, Chen, GH & Wu, J 2005, ‘An energy efficient unequal clustering mechanism for wireless sensor networks’, Proceedings of the IEEE International Conference on Mobile Ad-hoc and Sensor System, pp. 604-611.

Lianshan, Y, Wei, P, Bin, L, Xiaoyin, L &Jiangtao, L 2011, ‘Modified energy-efficient protocol for wireless sensor networks in the presence of distributed optical fiber sensor link’, IEEE Sensors Journal, vol. 11, no. 9, pp. 1815-1819.

Lijun, L, Hunt, W &Peng, C 2006, ‘Discuss in a round rotation policy of hierarchical route in wireless sensor networks’, Proceedings of IEEE International Conference on Wireless Communication, pp. 01-05.

Liu, B, Bras, P, Dousse, O, Nain, P &Towsley, DF 2005, ‘Mobility improves coverage of sensor networks’, Proceedings of the 6th ACM International Symposium on Mobile Ad-Hoc Networking and Computing, pp. 300-308.

Liu, Y, Gao, J, Jia, Y & Zhu, L 2008, ‘A Cluster maintenance algorithm based on LEACH-DCHS protocol’, Proceedings of the International Conference on Networking Architecture and Storage, pp. 165-166.

Ma, K, Zhang, Y & Trappe, W 2008, 'Managing the mobility of a mobile sensor network using network dynamics', IEEE Transactions on Parallel and Distributed Systems, vol. 19, no. 1, pp. 106-120.

Manjeshwar, A &Agarwal, DP 2001, 'TEEN: a routing protocol for enhanced efficiency in wireless sensor networks', International Workshop on Parallel and Distributed Computing Issues in Wireless Networks and Mobile Computing.

Mclurkin, J 1999, Algorithms for distributed sensor networks.Masters thesis for Electrical Engineering, University of California.

Meenakowshalya, A &Sukanya, A 2011, 'Clustering algorithms for heterogeneous wireless sensor networks-a brief survey', International Journal of Ad-hoc Sensor and Ubiquitous Computing, vol. 2, no. 3, pp. 57-69.

Mohammed, AM &Abdallah, B 2011, 'Cluster-based communication protocol for load-balancing in wireless sensor networks', International Journal of Advanced Computer Science and Applications, vol. 3, no. 6, pp. 105-112.

Moslem, AM 2014, 'Cluster head election using imperialist competitive algorithm (CHEI) for wireless sensor networks', International Journal of Mobile Network Communications and Telematics, vol. 4, no. 3, pp. 01-09.

Murugananthan, SD, Ma, DCF, Bhasin, RI &Fapojuwo, AO 2005, 'A centralized energy-efficient routing protocol for wireless sensor networks', IEEE Transactions on Communication Magazine, vol. 43, no. 3, pp. 08-13.

Nagpal, R &Coore, D 2002, 'An algorithm for group formation in an amorphous computer', Proceedings of IEEE Military Communications Conference.

Noritaka S, Hiromi M, Hiroki M &Michiharu M 2009, 'Centralized and distributed clustering methods for energy efficient wireless sensor networks', Proceedings of the International Multi-Conference of Engineers and Computer Scientists, vol. 01.

Pedro, AF, Alfonso, C &Georgios, BG 2011, 'Distributed clustering using wireless sensor networks', IEEE Journal of Selected Topics in Signal Processing, vol. 5, no. 4, pp. 707-724.

Qiang, T, Bingwen, W &Zhicheng 2009, 'MS-LEACH: A routing protocol combining multi-hop transmissions and single-hop transmissions', Proceedings of the Pacific-Asia Conference on Circuits Communications and Systems, pp. 107-110.

Ragaey, JM, Nikolic, B, Sangiovanni, V & Wright, P (eds.) 2001, Design Methodology for Pico-Radio Networks, Berkeley Wireless Research Centre.

Razieh, S, Sam, J & Ahmad, KZ 2011, 'Comparison of energy efficient clustering protocols in heterogeneous wireless sensor networks', International Journal of Advanced Science and Technology, vol. 36, pp. 27-40.

Salim, ELK, Nejah, N, Anne, W &Abdennaceur, K 2014, ‘A new approach for clustering in wireless sensors networks based on LEACH’, International Workshop on Wireless Networks and Energy Saving Techniques, vol. 32, pp. 1180-1185.

Sandell, N, Varaiya, P, Athans, M &Safonov, M 1978, ‘Survey of decentralized control methods for large scale systems’, IEEE Transactions on Automatic Control, vol. 23, no. 2, pp. 108-128.

Saravanakumar, R, Susila, SG & Raja, J 2011, ‘Energy efficient homogeneous and heterogeneous system for wireless sensor networks’, International Journal of Computer Applications, vol. 17, no. 4, pp. 33-38.

Saraydar, CU, Mandayam, NB & Goodman, DJ 2002, ‘Efficient power control via pricing in wireless data networks’, IEEE Transactions on Communication, vol. 50, no. 2, pp. 291-303.

Sedghani, H &Lighvan, MZ 2014, ‘PDH clustering in wireless sensor networks’, International Journal on Technical and Physical Problems of Engineering, vol. 6, no. 3, pp. 121-125.

Shalli, R, Jyoteesh, M & Rajneesh, T 2013, ‘EEICCP - Energy efficient protocol for wireless sensor networks’, Scientific Research-Wireless Sensor Network Journal, vol. 5, pp. 127-136.

Song, F & Zhao, B 2008, ‘Trust-based LEACH protocol for wireless sensor networks’, Proceedings of the 2nd International Conference on Future Generation Communication and Networking, pp. 202-207.

Taruna, S &Sakshi, S 2013, ‘A cluster based routing protocol for prolonging network lifetime in heterogeneous wireless sensor networks’, International Journal of Advanced Research in Computer Science and Software Engineering, vol. 3, no. 4, pp. 650-665.

Thangadurai, N &Dhanasekaran, R 2013, ‘Energy efficient cluster based routing protocol for wireless sensor networks’, International Journal of Computer Applications, vol. 71, no. 7, pp. 43-48.

Vaibhav, VD &Patil, ARB 2013, ‘Energy distributed clustering for improving lifetime of wireless sensor network’, International Journal of Emerging Science and Engineering, vol. 1, no. 7, pp. 62-65.

Varshney, P (eds.) 1997, Distributed Detection and Data Fusion, Springer from New York.

Vinay, K, Sanjeev, J &Sudarshan, T 2011 ‘Energy efficient clustering algorithms in wireless sensor networks: a survey’, International Journal of Computer Science Issues, vol. 8, no. 2, pp. 259-268.

Woo, A & Culler, D (eds.) 2005, Evaluation of Efficient Link Reliability Estimators for Low-Power Wireless Networks, UC Berkeley Technical Report.

Xu, Y, Heidemann, J &Estrin, D 2001, ‘Geography-informed energy conservation for ad-hoc routing’, ACM Special Interest Group on Mobility of Systems, pp. 70-84.

Yajie, M, Yike, G, Xiangchuan, T &Moustafa, G 2011, ‘Distributed clustering-based aggregation algorithm for spatial correlated sensor networks’, IEEE Sensors Journal, vol. 11, no. 3, pp. 641-648.

Yang, H &Sikdar, B 2007, ‘Optimal cluster head selection in the LEACH architecture’, Proceedings of the 26th IEEE International Conference on Performance Computing and Communications, pp. 93-100.

Yang, Y, Rick, SB & Brian, MS 2010, ‘A distributed and energy-efficient framework for neyman-pearson detection of fluctuating signals in large-scale sensor networks’, IEEE Sensors Journal, vol. 28, no. 7, pp. 1149-1158.

Ye, M, Li, CF, Chen, GH & Wu, J 2005, ‘EECS: An energy efficient clustering scheme in wireless sensor networks’, Proceedings of the 2nd IEEE International Performance Computing and Communications Conference, pp. 535-540.

Younis, M, Youssef, M &Arisha, K 2003, ‘Energy-aware management in cluster-based sensor networks’, Computer Networks Journal, vol. 43, no. 5, pp. 649-668.

Younis, O &Fahmy, S 2004, ‘HEED: A hybrid energy-efficient distributed clustering approach for ad-hoc sensor networks’, IEEE Transactions on Mobile Computing, vol. 3, no. 4, pp. 366-379.

Youssef, A, Younis, M, Youssef, M &Agrawala, A 2006, ‘Distributed formation of overlapping multihop clusters in wireless sensor networks’, Proceedings of the 49th Annual IEEE Global Communication Conference, pp. 01-06.

Yu, M, Li, JH & Levy, R 2006, ‘Mobility resistant clustering in multihop wireless networks’, Journal of Networks, vol. 1, no. 1, pp. 12-19.

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