A NOVEL STRATEGY FOR ATTAINING ENERGY EFFICIENCY IN DENSE WIRELESS SENSOR NETWORKS

N. Abhishek[1], A. Yashwanth Reddy[2]
[1,2]Assistant Professor, Department of CSE,
Sree Dattha Group of Institutions, Hyderabad, Telangana, India.

Abstract
Unfailing routing of packets from sensor nodes to its base station is the most significant function for these networks. The conservative routing protocols cannot be applied here due to its battery powered nodes. To provision energy efficiency, nodes are frequently clustered in to non-overlapping clusters. This paper gives a brief overview on clustering process in wireless sensor networks. A hybrid energy efficient distributed clustering methodology for dense wireless sensor networks, the Capacity based Clustering Low Energy Adaptive Clustering Hierarchy (CC-LEACH) has been proposed and the results have been evaluated against the existing Low Energy Adaptive Clustering Hierarchy (LEACH) clustering methodology. Simulation results clearly show an excellent improvement in throughput, packet delivery ratio and number of packets received at the base station. Also, the proposed clustering methodology show a reduction in packet drop, energy consumption and end to end latency for dense wireless sensor networks.
Keywords: Distributed clustering algorithm, coverage based clustering, energy efficiency, network lifetime.

I. INTRODUCTION

Commonly a wireless sensor node entails low power processor, tiny memory, radio frequency module, numerous kinds of sensing devices and limited powered batteries which treasures applicable in target tracking, environmental monitoring (figure 1) and agricultural applications. Much of energy consumption occurs during wireless communications. The energy consumption when transmitting one bit of data equivalents to numerous 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 investigators have projected numerous algorithms for WSNs to reduce energy consumption and increase the network lifetime. Since these wireless sensor devices are power-constrained, long-distance communications are not fortified [1]. Thereby direct communication amongst the nodes and base station is usually evaded. A gifted way is to arrange the network into numerous clusters (figure 2) and each individual cluster has a cluster-head (CH). A CH is one of the sensor nodes which is rich in resources. Sensor nodes send their sensed data to the CH during their corresponding TDMA time-slots. The CH executes data aggregation process and forwards the aggregated data to the base station (BS) [2].

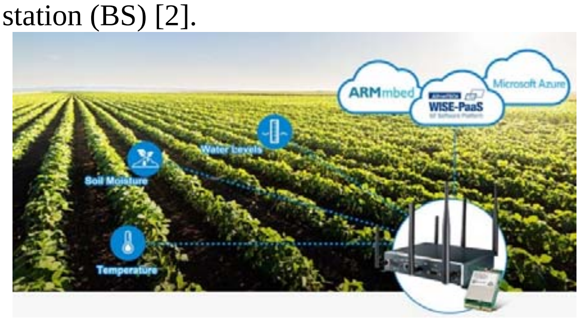

Figure 1: Environmental Monitoring Application of WSN

Clustering follows some benefits like network scalability, localizing route setup within the cluster, uses communication bandwidth proficiently and makes the best use of network lifetime [3]. Since clustering uses the mechanism of data aggregation, needless communication between the sensor nodes, CH and BS is avoided. A distributed clustering methodology, the Capacity based Clustering Low Energy Adaptive

Clustering Hierarchy (CC-LEACH) has been proposed and the results have been evaluated against the existing Low Energy Adaptive Clustering Hierarchy (LEACH) clustering methodology. The proposed algorithm 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 neighboring nodes [4-6]. The node with highest DOC is selected as a CH for the current round. The main objective of the proposed system is to accomplish energy efficiency and extended network lifetime. The rest of this paper is organized as follows. A review of distributed clustering algorithms for wireless sensor networks is discussed in Section II. The operations involved in the proposed CC-LEACH clustering algorithm have been elaborated in Section III. Section IV gives a brief elaboration of simulation results and discussions. Finally, the last section gives the conclusion.

II. REVIEW OF DISTRIBUTED CLUSTERING ALGORITHMS FOR WIRELESS SENSOR NETWORKS

Low Energy Adaptive Clustering Hierarchy (LEACH} is a clustering mechanism which distributes energy consumption all along its network, the network being parted into minor clusters and CHs which are purely distributed in manner and the randomly elected CHs, collect the data from the nodes which are coming under its cluster. The LEACH protocol contains four chief steps for each round: the advertisement phase, the cluster set-up phase, the schedule creation phase and the data transmission phase. During the first step, the advertisement phase, the eligible CH nodes will be delivering an announcement to the nodes coming under them to become a cluster member in its cluster [7].

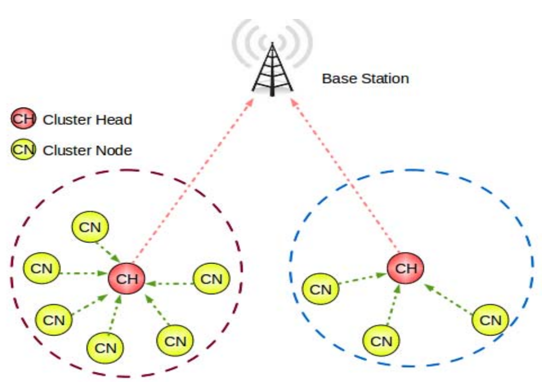

Figure 2: Clustering in Wireless sensor network

The nodes will be accepting the offer based on the received signal strength (RSS). In the cluster set-up phase, the sensor nodes will be answering to their selected CHs. In schedule creation step, as the CH accepts response from nodes it have to make a TDMA scheme and send it back to its cluster members to intimate them when they have to pass the data to it. In data transmission step, the data composed by the individual sensors will be given to the CH during their respective time intervals. The foremost restraint here is that, the radio of the cluster members will be turned off to diminish the energy consumption after the data transmission during particular slot is ended. Here in LEACH clustering protocol, multi-cluster interference problem was solved by using single CDMA codes for each cluster. The energy drain is prohibited for the same sensor nodes which have been elected as the cluster leader using randomization, for each time CH would be altered. The CH is responsible for collecting data from the cluster members and fusing it. Finally, each CH will be forwarding the fused information to the base station. LEACH shows a substantial improvement mainly in terms of energy-efficiency [8-10].

Hybrid Energy-Efficient Distributed Clustering (HEED) is a distributed procedure which selects the CH based on both residual energy and communication cost. Basically, HEED was suggested to avoid the random selection of CHs. Though LEACH protocol is much more energy efficient when compared with its antecedents (discussed below), the primary disadvantage of this method is the random selection of CH. In the worst case, the cluster head nodes may not be consistently distributed among the nodes and it will have its consequence on data gathering.

Linked Cluster Algorithm (LCA) is a distributed clustering algorithm that avoids communication collisions among sensor nodes and uses TDMA frames for inter-node communication, with each frame having a time slot for each node in the network for communication. Suggesting cluster formation and CH election algorithms, several papers focuses on single-hop clustering and thereby guarantees that no node will be more than one hop away from leader. In LCA, every nodes necessitates 2n time slots, where n is the number of nodes in the network, to have consciousness of all nodes in its neighborhood [11-13].

CLUBS algorithm uses the advantage of local communication to proficiently aggregate the nodes into clusters, in which the time reserved for convergence is proportional to the local density of nodes. In order that the clusters to be advantageous for resource allocation and self-organization, the clustering phenomenon in CLUBS is described by the following: First, every node in the network must apt to some cluster. Second, every cluster should be of equal diameter. Third, a cluster should have local routing, which means that every node inside the cluster should be able to communicate with each other using only nodes within that same cluster. The CLUBS algorithm forms coinciding clusters, with the maximum cluster diameter of two hops. 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 traces zero without being interrupted, the node becomes a CH and recruits its local neighborhood in to its cluster by broadcasting the recruit message.

Energy Efficient Hierarchical Clustering (EEHC) is a distributed and randomized clustering algorithm for WSNs, in which the CHs gather the data about the individual clusters and forward the aggregated report to the base-station. Their method is based on two phases: initial and extended. The initial phase which is also named as single-level clustering, in which each sensor node proclaims itself as a cluster head with a probability p to the neighboring nodes within its communication range. These CHs are named as volunteer CHs. All the nodes that are within k hops range of a CH receive this announcement either by direct communication or by forwarding. Any node that receives that announcements and is not itself a CH becomes the member of the closest cluster. Forced CHs are sensor nodes that are neither CHs nor fit in to a cluster. If the announcement does not reach to a node within the preset time interval t that is calculated based on duration for a packet to reach a node that is k hops away, the specific node will become a forced CH supposing that it is not within k hops of all volunteer CHs. In the second phase, the technique is prolonged to permit multi-level clustering and commonly builds h levels of cluster hierarchy. Thus, the clustering method is recursively repeated at the level of CHs to form an additional tier. The procedure guarantees h-hop connectivity between CHs and the base-station.

Fast Local Clustering Service (FLOC) is a distributed clustering technique that produces non-overlapping clusters and around equal-sized clusters. FLOC achieves locality: effects of cluster formation and faults or changes at any part of the network within almost two units distance. FLOC shows a double-band structure of wireless radio-model for communication. A node can communicate unfailingly with the nodes that are in the inner-band (i-band) range and unreliable communication with the nodes in its outer-band (o-band) range. Hence, the i-band nodes suffer very miniature interference communicating with the CH, thus it is a reliable communication. Messages from o-band nodes are unreliable during data communication and therefore it has the maximum probability of getting vanished during communication. FLOC is fast and scalable, therefore it achieves clustering in O(1) time irrespective of the size of the network. It also displays self-healing capabilities, since the o-band nodes can switch to i-band node in another cluster. It also completes re-clustering within constant time and in a local manner. It also achieve locality, in that each node is only influenced by the nodes within two units. These structures inspire FLOC algorithm to be suitable for large scale WSNs.

Algorithm for Cluster Establishment (ACE) is an extremely uniform cluster formation, self-organizing, slighter overlapping, efficient coverage and emergent cluster forming algorithm for WSNs, which is scale-independent and finishes in time proportional to the deployment density of the sensor nodes irrespective of the overall number of nodes in the network. ACE demands no knowledge of geographic location and necessitates only negligible amount of communication overhead. The important idea 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 balanced steps in ACE algorithm is spawning of new clusters and migration of the existing clusters. Spawning is the procedure by which a node becomes a CH. During spawning, when a node approves to become a cluster head, it broadcasts an invitation message to its neighbors. The neighboring nodes agree such invitation and become a follower of new CH. The principal distinctive feature of

ACE is that, a node can be a follower of more than one CH. During migration, best candidate for being CH is selected. Each CH will periodically check all its neighbors to regulate which node is the best candidate to become a cluster head for the cluster. The finest candidate is the node which, if it were to become a cluster head, would have the greatest number of follower nodes with minimum amount of overlap with the prevailing clusters. Once the best cluster head is determined by the current cluster head, it will uphold the best candidate as the new CH and steps down from its CH position [14].

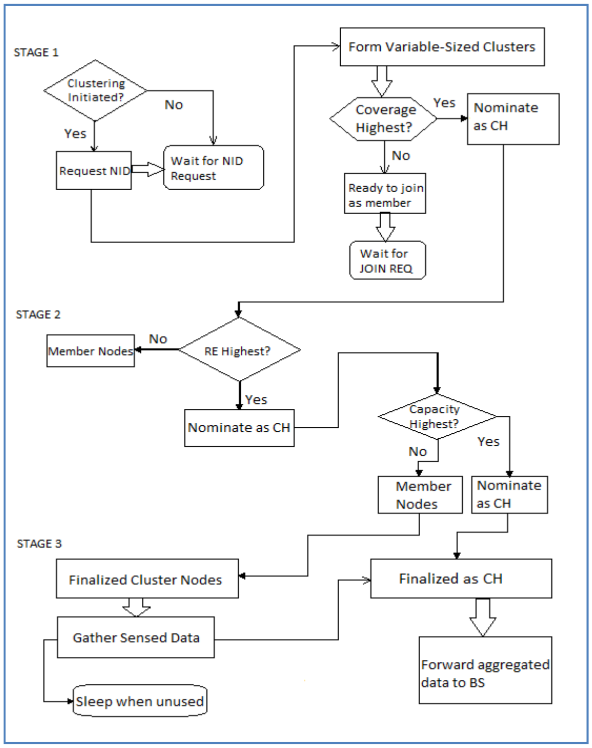

Figure 3: Cluster formation in CC-LEACH algorithm

III. THE PROPOSED CC-LEACH CLUSTERING METHODOLOGY

The proposed clustering algorithm is well distributed, where the sensor nodes are positioned randomly to sense the target environment. The nodes are distributed into clusters with each cluster having a CH. The nodes forward the information during their TDMA timeslot to their respective CH which fuses the data to avoid redundant data by the process of data aggregation. The aggregated data is forwarded to the BS. Compared to the existing procedures, the proposed procedure 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 decrease considerable power. Second, CH sends one message for every cluster nodes but many existing algorithms transmits several messages for cluster-setup. The main activity in a WSN is to effectively select a CH. This is attained by using numerous techniques. In the proposed algorithm, CH selection is accomplished with the use of the following parameters (figure 3).

A. *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 merely functions as recognition of the nodes and has no connection with location or clustering. The CH will be located at the center and the nodes will be systematized in to several layers around the CH and these layers are allotted 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 basically significant when a sensor network is used for remote monitoring applications. The nodes with maximum coverage between the cluster nodes are given highest priority to become a CH. Basically HEED was proposed to avoid random selection of CHs. Although LEACH was more energy efficient, the foremost 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 CC-LEACH algorithm.

B. *Highest Remaining Energy*

Remaining energy is defined as to energy remaining within a particular node after some number of rounds. This is normally 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 attempts to distribute the loading of CHs to all nodes in the network by switching the cluster heads occasionally. 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 reliant 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. Therefore, remaining energy is considered as one of the significant parameter for CH selection in the proposed CC-LEACH algorithm.

C. 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 swapping 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 arbitrary 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 necessary. 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 in the proposed CC-LEACH algorithm.

IV. SIMULATION RESULTS AND DISCUSSIONS

For simulation purpose, a sensor network of 50 sensor nodes is randomly organized over a 500 x 500 m^2 area. All the sensor nodes are expected to possess equal amount of initial energy. All the simulation mechanisms have been carried out using NS-2. The simulator contains of various components such as deployment component, topology construction component, mobility management component, medium access control component, routing component, energy expenditure computing component and throughput computing component.

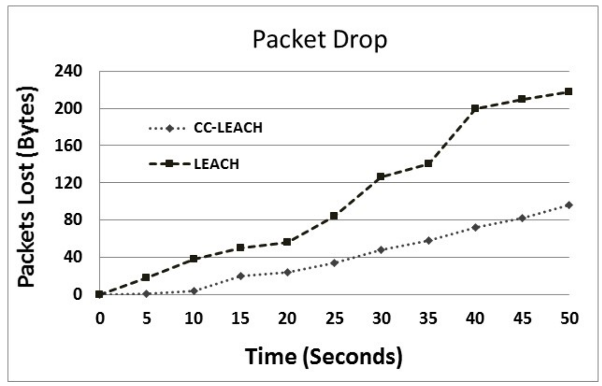

Figure 4: Comparison of Packet Drop in LEACH and CC-LEACH

Figure 4 shows the comparison of packet drop in LEACH and CC-LEACH. Packet drop occurs when one or more packets of data travelling across a sensor network fail to reach their destination. Packet loss is characteristically caused by network congestion. Packet loss is measured as a percentage of packets lost with respect to packets sent. Initially in 5 seconds, the packet loss in LEACH and CC-LEACH is 18 and 1 respectively. Similarly in 30 seconds, the packet loss in LEACH and CC-LEACH is 140 and 48 respectively. Finally at 50 seconds, the packet loss in LEACH and CC-LEACH is 218 and 96 respectively. The average packet loss in LEACH is 103.63 packets and the average packet loss in CC-LEACH is 39.905 packets. The proposed CC-LEACH mechanism shows 61.49% reduced packet loss when compared to the existing LEACH clustering mechanism.

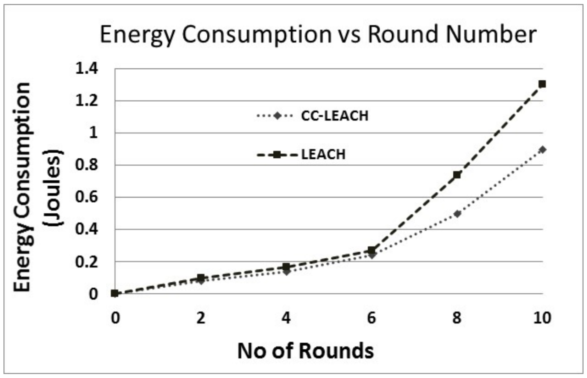

Figure 5: Comparison of Energy Consumption versus Round Number in LEACH and CC-LEACH

Figure 5 shows the comparison of Energy Consumption against Round Number in LEACH and CC-LEACH. Initially in 2 rounds, the energy consumption of CC-LEACH and LEACH are 0.08 Joules and 0.1 Joules respectively. Similarly in 10 rounds, the energy consumption of CC-LEACH and LEACH are 0.9 Joules and 1.3 Joules respectively. The proposed CC-LEACH clustering methodology shows a consistent reduction in energy consumption when compared to the existing LEACH clustering methodology. At an average, the energy consumption of LEACH and CC-LEACH are 0.43 Joules and 0.31 Joules respectively. The proposed CC-LEACH clustering methodology shows 27.90% reduced energy consumption when compared to the existing LEACH clustering methodology because of the novel clustering concepts employed in the proposed methodology.

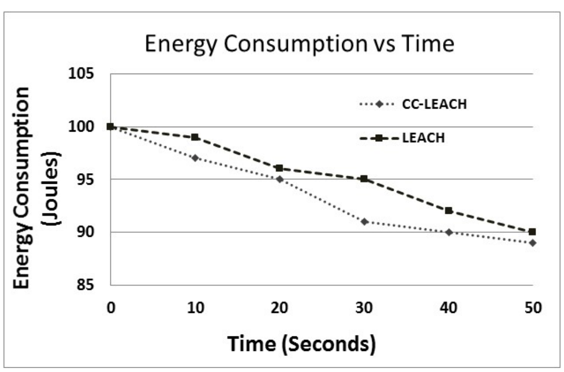

Figure 6: Comparison of Energy Consumption versus Time in LEACH and CC-LEACH

Figure 6 gives the comparison of Energy Consumption versus Time in LEACH and CC-LEACH. Energy consumption is an important issue in designing and implementing of Wireless Sensor Networks, which help the designers to optimize the energy consumption in WSN nodes. Reputable knowledge of the sources of energy consumption in WSNs is the first step to reduce energy consumption. Initially, at 10 seconds the energy consumption of LEACH and CC-LEACH are 99 Joules and 97 Joules respectively. Similarly at 50 seconds, the energy consumption of LEACH and CC-LEACH are 90 Joules and 89 Joules respectively. At an average, the proposed CC-LEACH clustering methodology shows a moderate difference on 1.67 Joules of reduced energy consumption for every 50 seconds when compared to the existing LEACH clustering methodology.

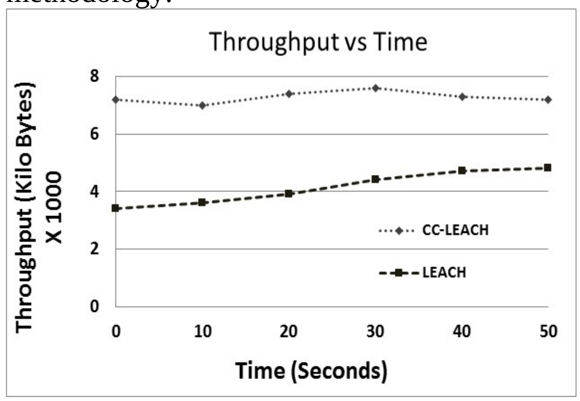

Figure 7: Comparison of Throughput versus Time in LEACH and CC-LEACH

Figure 7 shows the comparison of Throughput against Time in LEACH and CC-LEACH. Throughput is the measure of successfully delivered packets to the sink node or base station. Normally, the per node throughput in sensor networks is decreased with the increase in number of sensor nodes. Initially in 10 seconds, the throughput of LEACH and CC-LEACH are 3600 kilobytes and 7000 kilobytes respectively. Similarly in 50 seconds, the throughput of LEACH and CC-LEACH are 4800 kilobytes and 7200 kilobytes respectively. At an average, the proposed CC-LEACH clustering methodology shows 43.26% improvement in throughput when compared to the existing LEACH clustering methodology.

Figure 8 shows the End to end Delay comparison in LEACH and CC-LEACH. End-to-end delay refers to the time taken for a packet to be transmitted across a network from source to destination. Initially in 5 seconds, the end to end delay of LEACH and CC-LEACH are 1.92 milliseconds and 1.72 milliseconds respectively. Similarly in 50 seconds, the end to end delay of

LEACH and CC-LEACH are 1.94 milliseconds and 1.85 milliseconds respectively. The average end to end delay of LEACH and CC-LEACH are 1.934 milliseconds and 1.797 milliseconds respectively. The proposed CC-LEACH clustering methodology shows 7.08% reduced end to end delay when compared to the existing LEACH clustering methodology.

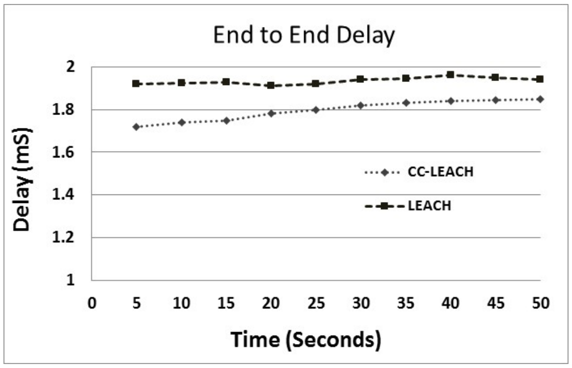

Figure 8: End to end Delay Comparison in LEACH and CC-LEACH

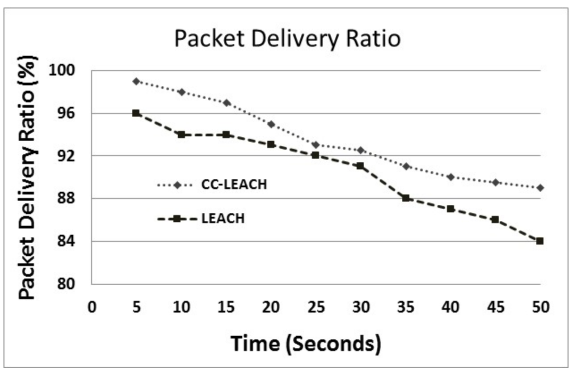

Figure 9: Packet Delivery Ratio Comparison in LEACH and CC-LEACH

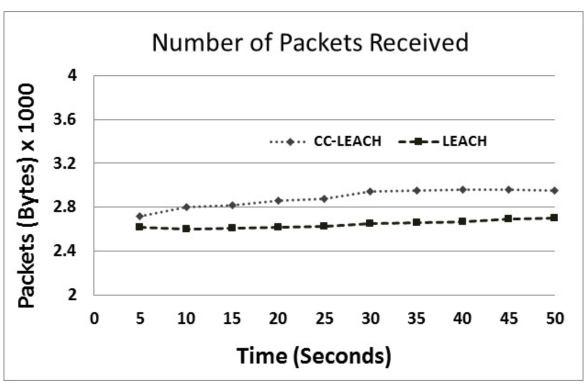

Figure 10: Number of packets received in LEACH and CC-LEACH

Figure 9 shows the Packet Delivery Ratio comparison in LEACH and CC-LEACH. Packet Delivery Ratio is the ratio of actual packet delivered to total packets sent. Initially in 5 seconds, the packet delivery ratio of LEACH and CC-LEACH are 96% and 99% respectively. Similarly in 50 seconds, the packet delivery ratio of LEACH and CC-LEACH are 84% and 89% respectively. At an average, the proposed CC-LEACH clustering methodology shows 2.90 % improvement in packet delivery ratio when compared to the existing LEACH clustering methodology.

Figure 10 elaborates the Number of packets received in LEACH and CC-LEACH. Initially in 5 seconds, the packets received at the base station in case of LEACH and CC-LEACH are 2620 bytes and 2720 bytes respectively. Similarly in 50 seconds, the packets received at the base station in LEACH and CC-LEACH are 2700 bytes and 2950 bytes respectively. At an average, the proposed CC-LEACH clustering methodology shows 8.32% improvement in packets received at the base station.

V. CONCLUSION

This paper gives a brief overview on clustering process in wireless sensor networks. A hybrid energy efficient distributed clustering methodology for dense wireless sensor networks, the Capacity based Clustering Low Energy Adaptive Clustering Hierarchy (CC-LEACH) has been proposed and the results have been evaluated against the existing Low Energy Adaptive Clustering Hierarchy (LEACH) clustering methodology. Based on the degree of capacity (DOC), the algorithm has been formulated to form efficient clusters in a wireless sensor network. Simulation results clearly show an excellent improvement in throughput, packet delivery ratio and number of packets received at the base station. Also, the proposed clustering methodology show a reduction in packet drop, energy consumption and end to end latency for dense wireless sensor networks. The proposed distributed clustering algorithm can show much improvement in communication energy.

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