ENHANCED ADAPTIVE CLUSTERING MECHANISM FOR EFFECTIVE CLUSTER FORMATION IN WSN

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Abstract

Reduced energy utilization is an exigent task for these sensor networks. In this paper hybrid energy efficient clustering algorithm for wireless sensor networks has been proposed, which mainly spotlights on reduction in energy utilization. It is a well distributed, energy efficient clustering algorithm which employs distributed relay nodes, adaptive transmission power and threshold-sensitive clustering mechanism for setting up the cluster. The proposed scheme is compared with the well-evaluated existing distributed clustering algorithms O-LEACH and HEED. Simulation results clearly depict an excellent advancement in remaining energy and throughput of the wireless sensor system. Simulation study also demonstrates an exceptional prolongation in network lifetime compared to the two existing clustering algorithms.

Keywords: **Wireless sensor network (WSN), distributed clustering, distributed relay node, adaptive transmission power, throughput, network lifetime.**

I. INTRODUCTION

A WSN can be generally styled as a network of nodes that cooperatively sense and regulates the environment. The activity of sensing, processing and communication under restricted amount of energy projects a need to pattern distributed mechanisms for data processing, MAC and communication protocols. Generally, a wireless sensor node is powered by limited-powered battery. Much of the energy consumption takes place during wireless communications. On the other hand, data processing in WSN requires consuming tasks to be accomplished to avoid unnecessary processing power. Energy efficiency can be accomplished at different levels starting from physical layer, MAC layer and routing protocols up to the application level.

The protocols in WSNs can be classed into three major categories: routing protocols, sleep/awake scheduling protocols and clustering protocols [8]. One prime method to attain energy efficiency is to efficiently group the sensor nodes into clusters (figure 2). In order to trim down the data transmission time and energy consumption, the sensor nodes are clustered into a number of small groups called clusters. The grouping of sensor nodes is known as clustering. Each and every cluster has a leader which is branded as cluster-head (CH). A CH is also one of the sensor nodes which are basically affluent in resources.

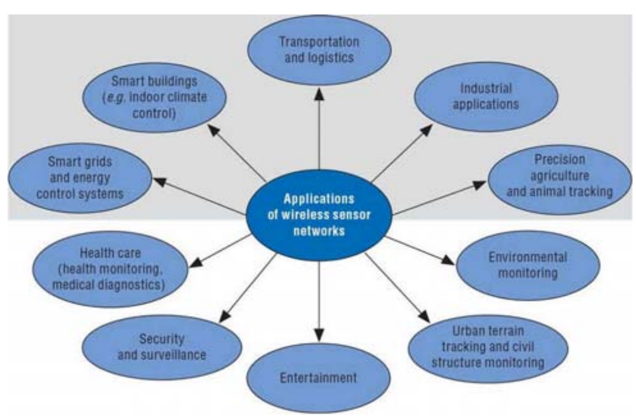

Figure 1: Typical applications of WSN

The CH is selected by the sensor nodes in the respective cluster. The CH may also be pre-assigned by the user. The main advantages of clustering are that it transmits the aggregated data to the sink or base station (BS), provides scalability for large number of nodes and diminishes the energy consumption. Clustering may be centralized or distributed, based on the planning of CH. In centralized clustering, the CH is fixed but in distributed clustering CH has no fixed architecture. Distributed clustering mechanism is used for some exclusive reasons like sensor nodes prone to failure, better collection of data and minimizing redundant information. Hence these distributed clustering mechanisms have highly self-organizing capability.

In this paper, a distributed clustering mechanism, Hybrid Energy Efficient Clustering Algorithm (HEECA) is proposed which is based on distributed relay nodes (DRN) for effectively connecting two WSN fields, adaptive transmission power for variable power usage for near/far located sensor nodes and threshold-sensitive clustering mechanism for cluster formation. The prime objective of the proposed algorithm is to achieve energy efficiency and extended network lifetime when two far-away located WSN fields are needed to be effectively coupled together for cooperative communication. The performance of the proposed clustering algorithm is evaluated against the two well evaluated existing algorithms Optical Low Energy Adaptive Clustering Hierarchy (O-LEACH) [1] and Hybrid Energy Efficient Distributed Clustering (HEED) [2].

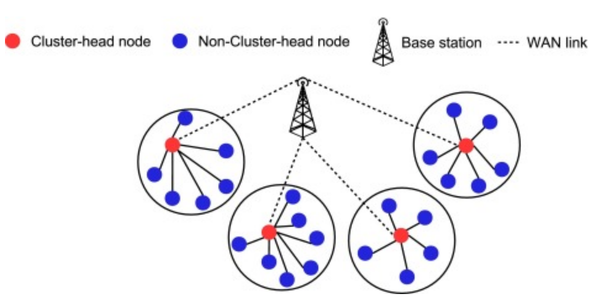

Figure 2: A method of cluster formation

The rest of this paper is organized as follows. A review of a handful of distributed clustering algorithms is discussed in Section II. Section III convolutes the description of the proposed algorithm. Simulation results with their discussions and briefed in Sections IV and V respectively. Finally, the last section concludes the paper artistically.

II. EXISTING DISTRIBUTED CLUSTERING ALGORITHMS

Algorithm for Cluster Establishment (ACE) [3] is a highly uniform clustering, self-organizing, effectual coverage, lesser overlapping and emergent cluster forming algorithm for WSNs. This is scale-independent and converges in time proportional to the deployment density of the nodes regardless of the overall number of nodes in the network. ACE requires no understanding of geographic location and requires only petite amount of communication overhead. In a distributed clustering algorithm, the nodes make autonomous decisions. In Hausdroff Clustering (HC), once cluster formations take place it remains unchanged throughout the network lifetime. Moreover, to evenly use the energy among all the nodes, CH is rotated among the cluster members. This algorithm expands the lifetime of each cluster in order to increase the life time of the wireless sensor system. CH selection is essentially based on residual energy of the sensor nodes. Clustering methods have reduced the running down of energy in WSNs. Ring-structured Energy-efficient Clustering Architecture (RECA) [4] uses deterministic CH management pattern to evenly distribute the work load among the nodes within a cluster. Nodes within a cluster make local assessments on the length of their duty cycle according to their remaining energies. RECA is effectual in managing energy in a wide range of networks settings.

Low Energy Adaptive Clustering Hierarchy (LEACH) [5] is a clustering mechanism that distributes energy consumption all along its network; the network is broken down into clusters. The CHs which are purely distributed in manner and the randomly elected CHs, gathers the information from the nodes which are coming under its cluster. It forms clusters based on the received signal strength and uses the CH nodes as routers to the BS. LEACH also forms one-hop intra and inter cluster topology where each node can transmit directly to the CH and thereafter to the BS. Consequently, it is irrelevant to networks deployed in wider regions. In the case of Two-Level Low Energy Adaptive Clustering Hierarchy (TL-LEACH), the CH collects data from other cluster members as original LEACH, but rather than transferring data to the BS directly, it uses one of the CHs that lie between the CH and the BS as a relay station. The primary CH in each cluster communicates with the secondaries, and the secondaries communicate with the nodes in their sub-cluster. Data fusion is also tasked as in LEACH. The two-level structure of TL-LEACH reduces the number of nodes, which need to transmit data to the BS, effectively lowering the total energy usage.

CLUBS [6] is an algorithm that forms clusters through local broadcast and converge in a time proportional to the local density of nodes. CLUBS can be implemented in asynchronous environment without losing efficiency and simplicity. Furthermore, CLUBS satisfies many constraints that are common in other distributed environment such as limited topology knowledge or access to global IDs. The major problem of CLUBS algorithm is the clusters having their CHs within 1-hop range of each other. If this is the case, both clusters will collapse and CH election process will restart. Multi-hop Overlapping Clustering Algorithm (MOCA) [7] is a randomized, distributed multi-hop overlapping clustering algorithm for organizing the sensors into overlapping clusters. The aspiration of the clustering process is to ensure that each node is either a CH or within the cluster radius from at least one CH. The CH nomination probability is used to control the number of clusters in the network and the degree of overlap amid them. In Threshold sensitive Energy Efficient Network (TEEN), at every cluster change time, in addition to the attributes, the CH broadcasts to its members. This scheme is eminently suited for time critical data sensing applications. A smaller value of the threshold gives a more accurate picture of the network, at the expense of improved energy consumption. Thus, the user can govern the trade-off between energy efficiency and accuracy.

The decentralized technique, Fast Local Clustering Service (FLOC) [8] is suitable for clustering large-scale wireless sensor networks. It is fast, scalable, produces non-overlapping and approximately equal-sized clusters. This algorithm achieves locality, in that each node is only affected by the nodes within two units. Distributed Weight-based Energy-efficient Hierarchical Clustering (DWEHC) [9] is a well distributed clustering algorithm which spawns well balanced clusters. The high-ranking advantage of DWEHC is that, it shows a vast improvement in both intra-cluster energy consumption and inter-cluster energy consumption.

The two distributed clustering algorithms that has fallen into our research interest are O-LEACH [1] and HEED [2]. In O-LEACH algorithm, the infrastructure of a sensor network is composed of a distributed optical fiber sensor (DFS) link and two separated WSN fields. The two WSN fields are crowded with randomly deployed nodes and these nodes can or cannot communicate with each other depending on the required applications. Unlike simple WSNs, since the DFS provide data processing, at one end of the DFS link, the sink or the BS for all WSN nodes is located. The CH node compress data arriving from nodes that belong to the relevant cluster, and sends the fused data to the BS in order to further reduce the amount of information to be transmitted to the BS. After a given interval of time, to maximize the uniformity of energy consumption of the network, randomized rotation of the role of CH is conducted. Sensors elect themselves to be local CHs at any time with a certain probability. The O-LEACH algorithm is only a fairly incremental modification to the original LEACH algorithm. Though O-LEACH protocol is comparatively much more energy efficient, the focal drawback in this approach is the random selection of CHs. In the worst case, the CH nodes may not be evenly distributed among the nodes and it will have its effect on the data gathering. Hybrid Energy Efficient Distributed Clustering (HEED) [2] is a distributed clustering algorithm which selects the CH based on both residual energy and communication cost. Principally HEED was proposed to avoid the random selection of CHs.

III. THE HEECA ALGORITHM

The proposed algorithm, hybrid energy efficient clustering algorithm (HEECA) (figure 3) is a well distributed clustering algorithm where the sensor nodes are deployed randomly to sense the target environment. The two WSN fields are coupled with the help of distributed relay nodes. The sensor network is partitioned into clusters with each cluster having an individual CH. The nodes send 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 distributed relay nodes which in turn routes the data to BS either directly or forwarding through other distributed relay nodes.

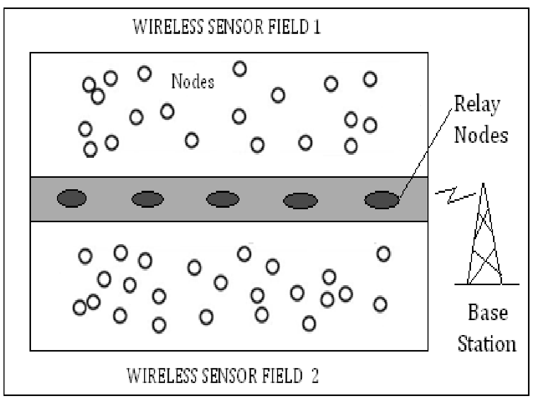

Figure 3: An articulation of HEECA algorithm

The proposed algorithm (HEECA) has four main peculiar features. First, CHs does not forward the data to BS, instead CH forwards data packets to distributed relay nodes and these richer-resourced distributed relay nodes routes data to BS thereby considerable energy utilization can be lessened. Second, HEECA uses adaptive transmission power. Nodes closer to CH use lesser transmission power and nodes far away from CH use maximum power for transmission from nodes to CH or vice versa, which trims down considerable power. Third, a hybrid clustering mechanism taking on the concept of threshold to avoid redundant information transmittal by the CH. Fourth, HEECA puts to use distributed relay nodes to connect two WSN fields.

Since the CHs or the regular sensor nodes automatically decides the transmission power based on its communication distance to that of the node to be communicated, it is referred as adaptive transmission power. The nodes in the cluster are divided into regions based on their distance from CH and region numbers are assigned. Lowest number is assigned to the nodes in the nearest region to CH.

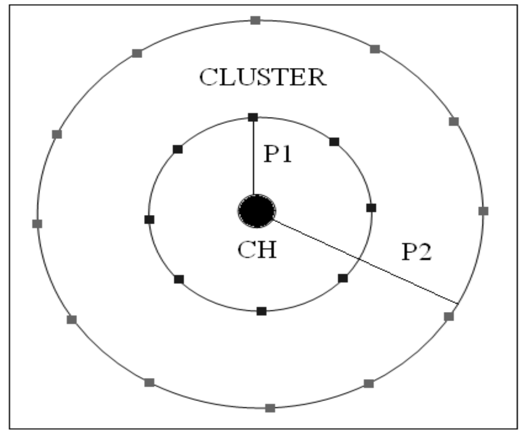

Figure 4: Adaptive transmission power in HEECA

The nodes in the farthest region are assigned with highest region number. The nodes in the last region use maximum transmission power and the nodes in the first region uses minimum transmission power. The concept of adaptive power transmission in HEECA is drafted in figure 4. Here the first region nodes utilizes power (P_1), the second region nodes utilizes power (P_2) and so on. The transmission power increases with increase in region number.

A distributed relay node (DRN) is a node which is wealthy in resources like battery, memory, etc. In general, similar to the sensor nodes, DRNs are also battery operated devices gifted for wireless communication. The DRNs may also shorten the transmission distance between a pair of distantly located nodes by acting as a hop between them. But the type of DRNs proposed in different publications is not one-off. It has been suggested that DRNs should be of prominent capabilities than the sensor nodes in terms of initial energy provisioning, the transmission range and the data processing (data gathering and data aggregation) capability.

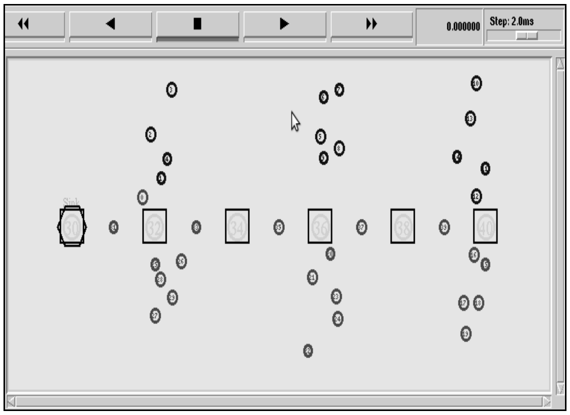

Figure 5: Snapshot representing two WSN fields connected by distributed relay nodes in HEECA algorithm

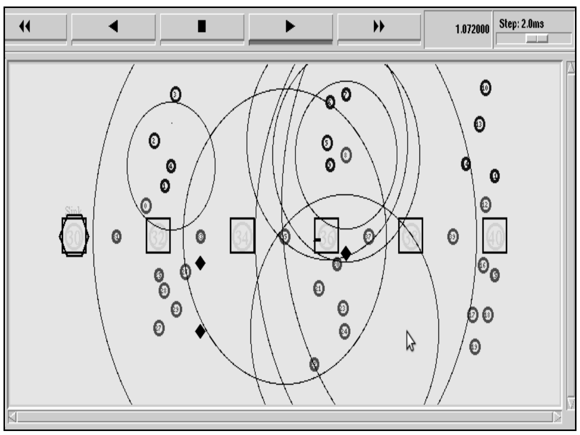

Figure 6: Cluster head rotation in HEECA algorithm

In the proposed algorithm (figure 5), the DRNs perform two core functions: first, it routes the aggregated data from CH to the BS either directly or forwarding through other DRNs and second, it is used to provide wireless connection between two WSN fields. In the proposed algorithm, the DRNs are distributed evenly within the coverage range of the two WSN fields. The main rewards of using DRNs: extends the lifetime of sensor networks, energy-efficient cum balanced data gathering, providing fault tolerance in sensor networks and providing wireless connectivity between two WSN fields.

Figure 6 portrays the mechanism of CH re-election in HEECA algorithm. The proposed algorithm HEECA uses a hybrid clustering mechanism (figure 7) for organizing the sensor nodes into clusters. The sensor network with 'N' nodes gets parted into 'n' individual clusters. Initially, a node with highest residual energy (RE) and good coverage with all the cluster nodes is elected as CH. The remaining nodes join to that particular CH as member nodes. The CH periodically checks the RE and coverage of the member nodes with its own and if it finds any node to have it higher, the CH role is transferred to that particular node with higher capabilities.

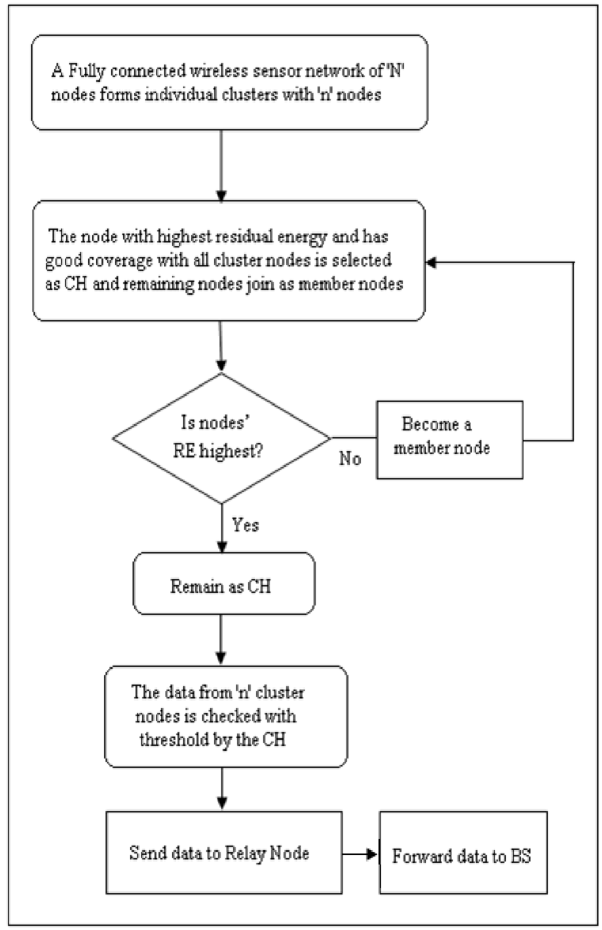

Figure 7: Hybrid cluster formation in HEECA

IV. SIMULATION STUDY

The following assumptions are made in HEECA: (i) Sensor nodes, CH, DRNs and BS are stationary. (ii) DRNs are exclusively rich in resources. (iii) Nodes use adaptive power for transmitting the data. (iv) Nodes are all location-unaware. (v) Clustering process is purely distributed. (vi) Clustering process must terminate after particular interval. (vii) CHs have higher residual energy compared to ordinary nodes. All the simulations were carried using the network simulator NS-2. For energy consumption, the first-order radio model outlined in [5] was employed. For simulation purpose, nodes were deployed randomly on the basis of the parameters outlined in table 1.The proposed distributed clustering algorithm is simulated with 30 nodes and at each time the energy utilization, node's residual energy, etc are recorded. Finally HEECA is compared with the existing clustering algorithms O-LEACH and HEED based on the above recorded readings. A data collection process is said to be ended up when all the relay nodes in the sensor network forwards the data to the BS. Sensor nodes are deployed in a square sensing field (x, y) of 500 x 500 meter^2. Once deployed the sensor nodes are assumed to be immobile. The DRNs are evenly distributed between the two WSN fields. The BS contains sufficient energy and at any cost energy scarcity does not occur. The sensor nodes have limited energy with initial energy of 10 Joules. When the energy is dropped to 0 Joule, the node is considered to be dead. The position of CH changes when its residual energy decreases compared to that of its cluster nodes.

Table 1: Simulation parameter setup

Parameter	Values
Topology	500x500 m^2
Data packet size	4000 bytes
Control packet size	550 bytes
Initial energy	100 Joules
Transmitter power	31.32 mW
Receiver power	35.28 mW
Ideal power	712 mW
Sleep power	144 mW

The relay nodes are assumed to be in sleep mode lest the CHs send the data to it. The core feature of the proposed algorithm is that, CHs does not forward all the data collected from the sensor nodes to the DRNs. Instead, it compares the collected data with the threshold values and sends only limited number of data to the DRNs. Thus redundant data packet transmission is reduced, which lowers energy utilization and increases the network throughput. The DRNs forward the data received from CH to the BS either directly or hopping through other DRNs.

The proposed algorithm HEECA is simulated and the results are recorded for network lifetime against number of rounds, energy remaining against time, energy consumption and throughput against number of rounds. These parameters are then assessed with the well evaluated existing algorithms O-LEACH and HEED. First, the performance of HEECA in terms of the network lifetime has been contrasted with O-LEACH and HEED. From figure 8, the network lifetime of HEECA increases extensively when compared to O-LEACH and HEED. This is because HEECA employs adaptive transmission power, DRNs for forwarding data from CH to the BS and by the usage of hybrid clustering mechanism. Second, the performance of HEECA in terms of remaining (residual) energy is evaluated against O-LEACH and HEED (figure 9). At 20 seconds the percentage of remaining energies of O-LEACH, HEED and HEECA are 40%, 45% and 50% respectively. A 10% increase and 5% increase in remaining energies is seen in HEECA in comparison with O-LEACH and HEED even at the very beginning, which is due to the hybrid cluster formation technique. At 130 seconds the percentage of remaining energies of O-LEACH, HEED and HEECA are 6%, 8% and 12% respectively. The percentage of remaining energy improvement is linearly maintained by HEECA until the last node ceases functioning.

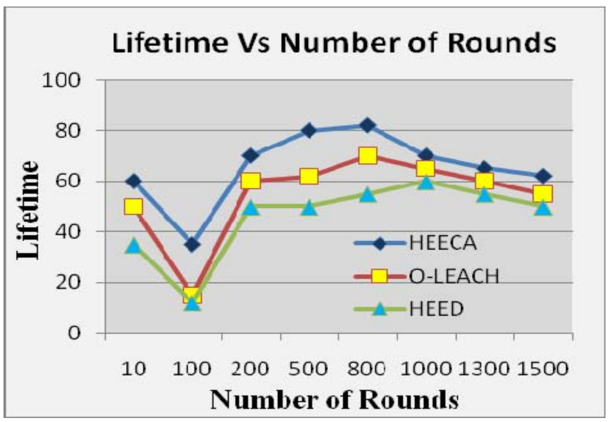

Figure 8: Lifetime against number of rounds (HEECA, O-LEACH and HEED)

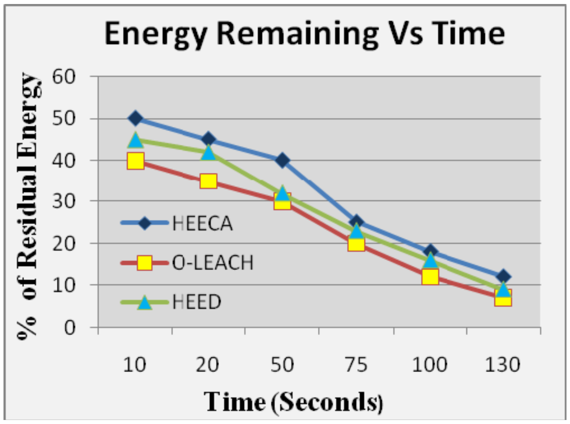

Figure 9: Remaining energy versus number of rounds (HEECA, O-LEACH and HEED)

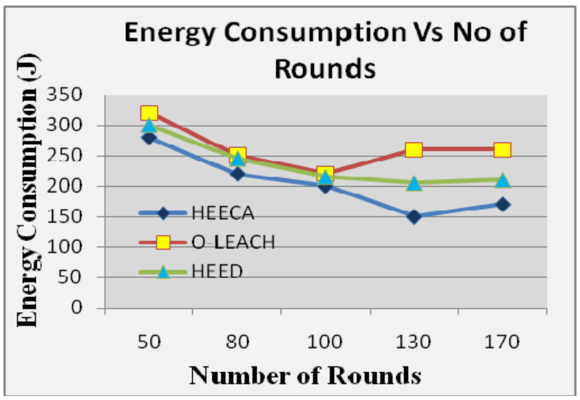

Figure 10: Energy Consumption against number of rounds (HEECA, O-LEACH and HEED)

Third, the performance of HEECA in terms of energy consumption is compared with O-LEACH and HEED (figure 10). Throughout the mechanism, energy consumption of HEECA is less when compared to O-LEACH and HEED. This lesser energy consumption is attained at the clustering level, DRN level and mainly due to variable power transmission employed by the cluster nodes to transmit data to their respective CHs and vice versa. Less energy is expended by the nodes that are nearer to CH and maximum energy is expended only by the nodes that are far away from CH. But, in the existing algorithms maximum energy is exhausted by the nodes that are both nearer and far away from the CH.

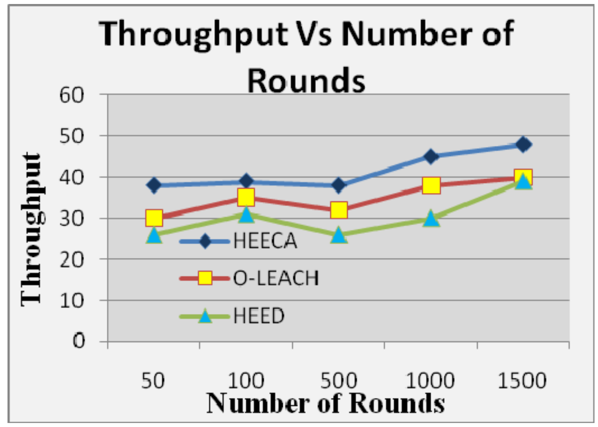

Figure 11: Throughput versus number of rounds (HEECA, O-LEACH and HEED)

Fourth, the performance of HEECA in terms of throughput is evaluated against O-LEACH and HEED (figure 11). It is lucidly seen that the throughput of HEECA is enhanced when compared with O-LEACH and HEED. From 50 to 1500 rounds, the throughput of HEECA is found to be greater than O-LEACH and HEED. This is because of the threshold comparisons labored at the CH level. Needless transmissions are averted by the CH to DRNs. Also the data packets are transmitted by the CH to DRNs only at fixed intervals of time (reduced number of transmissions by CH to DRNs). Thus, in HEECA the packets are meritoriously transferred to BS with scarcer drops when compared to O-LEACH and HEED.

V. CONCLUSION

In this paper a well distributed clustering algorithm, hybrid energy efficient clustering algorithm (HEECA) has been proposed, in which the optical fiber link is supplemented by distributed relay nodes for connecting two WSN fields. Based on hybrid clustering mechanism for cluster-setup, adaptive transmission power and distributed relay nodes, the algorithm HEECA has been formulated to form efficient clusters in a wireless sensor network to connect two WSN fields. The algorithm is analyzed and the performances are contrasted with the two well evaluated existing clustering algorithms O-LEACH and HEED. It is clearly seen that the proposed distributed clustering algorithm has shown much improvement in remaining energy and energy consumption over the existing algorithms. The evaluation of the proposed algorithm shows a drastic improvement in the throughput of the wireless sensor system. Nevertheless, the proposed algorithm can greatly prolong the overall network lifetime of the wireless sensor system.

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