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Variable Power Energy Efficient Clustering for Wireless Sensor Networks

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Abstract : Wireless sensor networks (WSN) are inheriting many application areas like environment observation, target tracking, border monitoring and battle field surveillance. To alleviate the problem of energy utilization and extending the lifetime of wireless sensor nodes, one approach is employing an effective clustering mechanism. In this paper variable power energy efficient clustering (VEEC) mechanism for wireless sensor networks has been proposed. It is a well distributed, energy efficient clustering algorithm which employs relay nodes, variable transmission power and single message transmission per node for setting up the cluster. The proposed scheme is compared with two existing distributed clustering algorithms LEACH and HEED. Simulation results clearly show an excellent improvement in average communication energy and the total energy of the wireless sensor system. Simulation study also shows the reduction in node death rate and prolongation in network lifetime compared to the two existing algorithms.

Key words: Wireless sensor network (WSN), distributed clustering, variable transmission power, relay node, energy efficiency, network lifetime

INTRODUCTION

Wireless sensor networks find its application in numerous real-time applications such as home automation, robot control, disaster relief, environment monitoring, sea labs, battlefield surveillance and automatic manufacturing. These WSNs can be used in remote areas like river, mountain, bridge, road and in harsh areas like desert. WSNs can also be used to prevent and make alerts on natural calamities. A wireless sensor network consists of thousands of sensor nodes that are used to sense the target information and transmitting them to the base station (BS) located far away from the sensing field. The main features of these networks are less mobility, less hardware capabilities, reduced memory and increased population density in the target area, when compared to ad-hoc networks (Younis and Fahmy, 2004).

Generally, a wireless sensor node consists of low power processor, tiny memory, radio frequency module, sensing devices and limited powered batteries (Akyildiz *et al*., 2002). Much of energy consumption takes place during wireless communications. The energy consumption when transmitting one bit of data equals to several thousands of cycles of CPU instructions (Pottie and Kaiser, 2000). Hence the energy efficiency of a wireless communication protocol greatly affects the energy efficiency and lifetime of the network (Zairi *et al*., 2012) and (Pedro Forero *et al*., 2011). Many researchers have proposed several algorithms for WSNs to improve energy consumption and network lifetime. The concerning protocols in WSNs can be classified into three major categories: routing protocols (Chang and Tassiulas, 2004), sleep/awake scheduling protocols (Deng *et al*., 2005) and clustering protocols (Wen and Sethares, 2005).

Since these devices are power-constrained, long-distance communications are not encouraged. Thereby direct communication between the nodes and base station is avoided. An efficient 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 rich in resources. Sensor nodes send their sensed information to the CH during their TDMA time-slots. The CH performs data aggregation process and forwards the fused data to base station. Clustering follows some advantages like network scalability, localizing route setup within the cluster, conserves communication bandwidth and maximizes network lifetime. Since clustering uses the mechanism of data aggregation, unwanted communication between the sensor nodes, CH and BS is avoided.

Clustering may be centralized or distributed, based on the architecture of CH. In centralized clustering, the CH is fixed and the remaining nodes of the cluster act as member nodes (Murugananthan *et al*., 2005) and (Bajaber and Awan, 2009). Distributed clustering has no fixed architecture for CH and this keeps on changing from node to node based on some pre-assigned parameters like residual energy, communication cost, weight and so on (Noritaka Shigei *et al*., 2009) and (Lianshan Yan *et al*., 2011). Distributed clustering architecture is used for some specific reasons like sensor nodes prone to failure, better collection of data, minimizing redundant information and providing backup in case of failure of the central node thereby having high self-organizing

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capability.

In this paper, a distributed clustering algorithm VEEC is proposed which is based on variable transmission power, relay nodes and single message per node for cluster-setup. The primary objective of the proposed algorithm is to achieve energy efficiency and extended network lifetime. The performance of the proposed algorithm is evaluated against two existing algorithms, namely Low Energy Adaptive Clustering Hierarchy (LEACH) (Heinzelman *et al*., 2002) and Hybrid Energy-Efficient Distributed Clustering (HEED) (Younis and Fahmy, 2004). The rest of this paper is organized as follows. A review of existing distributed clustering algorithms is discussed in Section II. The model of the proposed algorithm is described in Section III. Section IV elaborates the description of the proposed algorithm. Simulation results and their discussions and elaborated in Sections V and VI, respectively. Finally, Section VII gives the conclusion.

Review of Existing Distributed Clustering Algorithms:

Considerable research efforts have been made to minimize the energy consumption and to prolong the lifetime of WSNs. The algorithms described here are completely distributed and CH changes from node to node based on some parameters. They differ mainly in the methodology by which the CH is elected.

One of the well-known clustering algorithm is Energy-Efficient Hierarchical Clustering (EEHC) (Zairi *et al*., 2012), a randomized clustering algorithm organizing the sensor nodes into hierarchy of clusters with an objective of minimizing the total energy spent in the system to communicate the information gathered by the sensors to the information processing center. It has variable cluster count, the stationary CH aggregates and relays the data to the BS. It is applicable for numerous large scale networks. The main drawback of this algorithm is that, some nodes remain un-clustered during the clustering process.

Another clustering algorithm, Linked Cluster Algorithm (LCA) (Barker *et al*., 1984) was mainly implemented to avoid the communication collisions among the nodes by using a TDMA time-slot. It uses a single-hop scheme, attains high degree of connectivity when CH is selected randomly. The revised version of LCA, the LCA2 was implemented to decrease the number of nodes compared to the original LCA algorithm. The main disadvantage of this algorithm is, the single-hop clustering results in the formation of many clusters and hence much energy is wasted.

With an objective to form overlapping clusters with maximum cluster diameter of two hops, CLUBS (Nagpal and Coore, 2002) was implemented in WSNs. The clusters are formed by local broadcasting and its convergence depends on the local density of the sensor nodes. This algorithm can be implemented in asynchronous environment without losing efficiency. The main drawback is the overlapping of clusters, clusters having their CHs within one hop range of each other, thereby both clusters will collapse and CH election process will restart.

Fast Local Clustering Service (FLOC) (Demirbas *et al*., 2004) achieves re-clustering in constant time and in a local manner in large scale networks, exhibits double-band nature of wireless radio-model for communication. The nodes can communicate reliably with the nodes in the inner-band range and unreliably with the nodes that are in the outer-band range. It is fast, scalable and exhibits self-healing capabilities. The main drawback of the algorithm is, the nodes in the outer band use unreliable communication and the messages have the maximum probability of getting lost during communication.

According to Energy Efficient Clustering Scheme (EECS) (Ye *et al*., 2005), all CHs can communicate directly with base station. The clusters have variable size, such that those nearer to the CH are larger in size and those farther from CH are smaller in size. It is proved to be energy efficient in intra-cluster communication and excellent improvement network lifetime. Energy Efficient Unequal Clustering mechanism (EEUC) (Li *et al*., 2005), was proposed for uniform energy consumption within the network. It forms unequal clusters, with an assumption that each cluster can have variable sizes. Probabilistic selection of CH is the main drawback of this algorithm. Few nodes may be left out without being part of any cluster, thereby no guarantee that every node takes part in clustering mechanism.

Based on nodes' residual energy, connectivity and a unique node identifier, the cluster head selection is accomplished in Distributed Efficient Clustering Approach (DECA) (Yu *et al*., 2006). It is highly energy efficient, as it uses fewer messages for CH selection. The main problem with this algorithm is that high possibility of wrong CH selection which leads to discarding of all the packets sent by the sensor node.

In order to select CH based on weight: a combination of nodes' residual energy and its distance to neighboring nodes, Distributed Weight-based Energy-efficient Hierarchical Clustering (DWEHC) (Ding *et al*., 2005) has been proposed. It generates well balanced clusters, independent on network topology or size. A node possessing largest weight in a cluster is selected as CH. The algorithm constructs multilevel clusters and the nodes reach CH by relaying through other intermediate nodes. It shows a great improvement in intra-cluster and inter-cluster energy consumption. The main problem occurs due to much energy utilization by several iterations until the nodes settle in most energy efficient topology.

The distributed clustering algorithms which have fallen into the scope of this paper are LEACH (Heinzelman *et al*., 2002), and HEED (Younis and Fahmy, 2004). These algorithms organize networks with different network topologies. The operations of LEACH and HEED are briefly discussed as follows.

Low Energy Adaptive Clustering Hierarchy (LEACH) is a distributed clustering algorithm which forms multiple clusters with two-hop topology. Initially in each cluster, one node is randomly selected as CH. A CH collects sensor information from its member nodes during their TDMA timeslot. As the collected data is highly correlated, multiple data packets are fused in to a single packet by the process of data aggregation and the fused data is reported to the BS. In (Heinzelman *et al*., 2002), it is shown that networks with LEACH have prolonged network lifetime than those with direct transmission. It is particularly easy to implement and its decentralized properties makes it robust to intentional attacks. The drawbacks are, the nodes are assumed to be static and the scalability is however limited. Also the CHs are selected in a random fashion.

Hybrid Energy-Efficient Distributed Clustering (HEED) is a well distributed clustering algorithm in which CH selection is done by taking into account the residual energy of the nodes as well as intra-cluster communication cost leading to prolonged network lifetime. In (Younis and Fahmy, 2004), it is clear that it can have variable cluster count and supports heterogeneous sensor nodes. The CH is stationary which performs data aggregation and relaying of the fused data to BS. The problems with HEED are its application limited only to static networks, the employment of complex probabilistic methods and multiple clustering messages per node for CH selection even though it avoids random selection of CH.

The Model of VEEC:

The proposed algorithm, variable power energy efficient clustering (VEEC), is a well distributed clustering algorithm where the sensor nodes are deployed randomly to sense the target environment. The nodes are partitioned into clusters with each cluster having a 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 relay nodes which in turn routes the data to BS either directly or forwarding through other relay nodes.

Compared to the existing algorithms, VEEC has three distinguishing features (Figure 1). First, in many clustering algorithms CH forwards the data to BS directly, which leads to power wastage but in VEEC, CHs does not forward the data to BS. Instead CH forwards data packets to relay nodes and these richer resourced relay nodes routes data to BS thereby considerable energy utilization can be reduced. Second, VEEC uses variable transmission power. Nodes nearer to CH use lesser transmission power and nodes far away from CH use more power for transmission from nodes to CH or vice versa, which can reduce considerable power. Third, CH sends one message for every cluster nodes but many existing algorithms transmits several messages for cluster-setup.

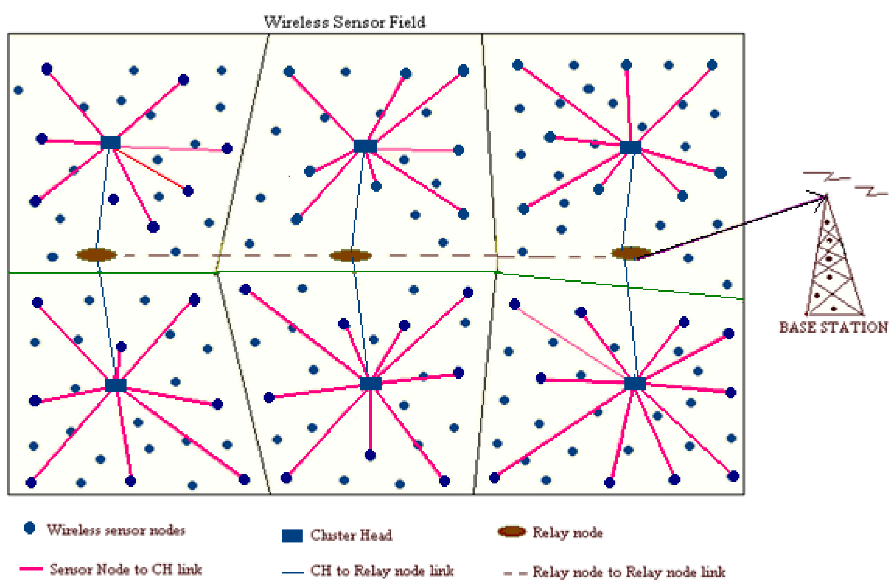

Fig. 1: An articulation of VEEC clustering algorithm

\Variable Transmission Power:

In a network of N nodes, each node is assigned a unique Node Identity (NID) represented by n, where n=1, 2, 3…., N. The NID just serves as an identification of the nodes and has no relationship with location or clustering. The CH will be located 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 starting from zero. CH gets LN0, nodes surrounding the CH in the next layer are assigned LN1, and so on. The nodes in the outermost layer get the highest LN. Nodes in first layer use lesser transmission power. The nodes in the last layer use maximum transmission power. The power transmission is variable and purely based on the layers, thereby VEEC attains excellent power conservation. The concept of variable power transmission in VEEC is depicted in figure 2. Here the first layer nodes utilizes power (P_1), the second layer nodes utilizes power (P_2) and so on. It is to be noted that the transmission power increases with increase in layer number. The transmission power required for a node in layer M is,

$$P_M = M \times P_1 \quad (1)$$

where, P_M is the transmission power of a node in layer M, P_1 is the transmission power of a node in first layer and M is the layer number.

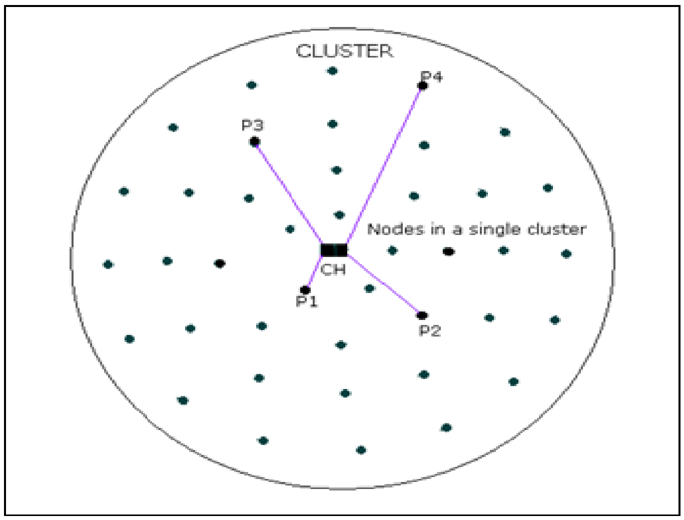

Fig. 2: The concept of variable power in VEEC

Relay Nodes:

A relay node is simply a node which is rich in resources like battery, memory, etc. In the proposed algorithm, the relay nodes perform only the routing of data to BS either directly or forwarding through other relay nodes (Figure 3). In VEEC, the main fact to be considered is that the relay nodes nearer to BS requires more transmission power as they have to forward all the data packets from the preceding relay nodes.

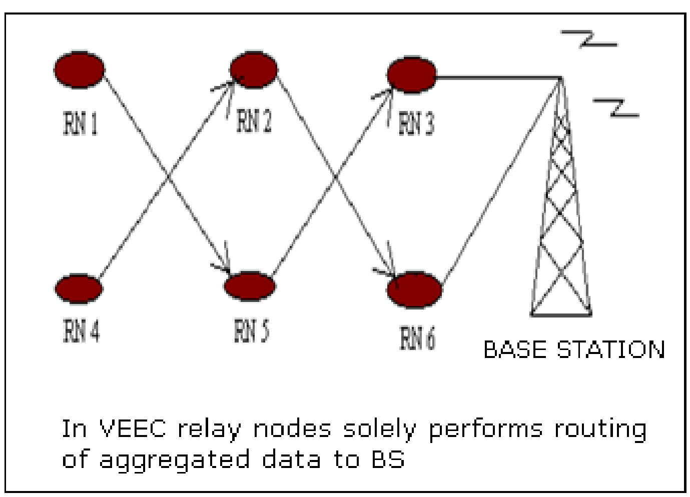

Fig. 3: The concept of relay nodes in VEEC

The power consumption of a relay node is proportional to its location and number of relay nodes around it. If the power consumption of the sensor node is ($\lambda e_t+\sigma$), the relay node density at a distance 'z' meters from BS is given by,

$$\rho_r(z) = \frac{w(z)}{(\lambda e_t + \sigma)} \tag{2}$$

where, parameter $\rho_r(z)$ is the relay node density at a particular distance 'z' meters from BS, w is the width of the sensing field, e_t is the energy required to transmit unit data, λ is the data gathering rate of each sensor node and σ is the power consumption of each sensor node spent in sensing. Hence in VEEC, based on $\rho_r(z)$ more relay nodes are placed in region nearer to BS and few relay nodes are placed at regions far away from BS.

Number of Messages for Clustering:

The proposed algorithm VEEC uses a single message for cluster-setup. Initially in each cluster one of the nodes with relatively higher residual energy assumes itself as a Provisional Cluster head (PCH). It sends a message to its member nodes, in turn gathers their residual energy and NID during their respective TDMA timeslots. It compares its residual energy with those of cluster nodes' and if it finds any node with higher residual energy, PCH transfers its CH role to that particular node thereby CH gets assigned. The CH sends a single message to the member nodes requesting their residual energies and NIDs. In turn the nodes send their residual energy and NID to CH during their TDMA timeslot, unnecessary transmissions are avoided thereby reducing power utilization and prolonging the network lifetime.

Algorithm Description:

In the proposed algorithm VEEC, the network consists of N nodes, Node Identity (NID) represented by n and the number of clusters formed is represented as K, K=1, 2,…., (N-1)/2. The entire algorithm (Figure 4) executes in four stages: cluster-setup, data aggregation, relay node's operation and CH re-election.

Stage I – Cluster Setup:

In VEEC, the node with highest residual energy has the maximum probability of becoming a CH. Initially PCH compares the residual energy (RE) of the cluster nodes and transfers the CH to the node having highest residual energy within a cluster. If it does not find any node having higher residual energy PCH itself will become a CH. It broadcasts join-request to the nodes within R meters, where R is equal to the cluster radius. The broadcast message includes the NID of the CH, the total number of layers in the cluster and local communication radius R_{COMM}. The objective of this message is to suppress other node's interest to become a CH. Nodes receiving this message will stop their action and joins to that CH.

As discussed earlier, the clusters are arranged in concentric layers, the sensor nodes will make use of messages in the packet and with the following equation to calculate the bound B_K of the K^{th} layer, where K=1, 2,….…, L_T.

$$B_K = b_{k-1} + R_{COMM} \tag{3}$$

where b_{K-1} is the average distance between CH and the cluster member in the $K\text{-}1^{th}$ layer. L_T is the total number of layers in the cluster. Here b_{K-1} is expressed as,

$$b_{k-1} = \sqrt{\frac{B_{K-1}^2 + B_{K-2}^2}{2}} \tag{4}$$

The cluster members will make use of received signal strength indicator (RSSI) and the link quality indicator (LQI) of the CH to estimate their distances from CH and calculates their respective layers. Variable power can be thus effectively employed for transmitting data from nodes to CH and vice versa.

Stage II – Data Aggregation:

A CH will fuse all the incoming data packets together, those received from the sensor nodes in order to avoid redundant data transmission of highly correlated data. The fused data is then forwarded to relay nodes. In case when a node dies or does not transmit the data during its time-slot, it is regarded as unreachable and can be skipped from the data collection process. The aggregation is performed by spatial correlation measurement by measuring the offset between the two sensor readings. If the error is within the tolerable range, then the two readings are correlated.

Stage III– Functionality of Relay Node:

In VEEC the relay nodes are static and only forward the data to BS. Every relay node has the same initial energy and transmission range. The MAC protocol puts the radio of the relay node in sleep mode if it is not the transmitter or receiver of the packet. The relay nodes are divided into different zones starting from the BS. The relay nodes in the zone nearer to the BS need to relay more packets and hence more number of relay nodes has to be placed in the zone nearer to BS. The zone farther from BS requires fewer number of nodes as there is need for only little amount of data to be forwarded. Also the power consumption of the relay nodes nearer to BS will be more compared to the relay nodes far away from BS. The BS will periodically broadcast a beacon message to the relay nodes. The relay nodes use the RSSI and LQI of the beacon message to estimate its distance from BS in order to maintain the transmission power.

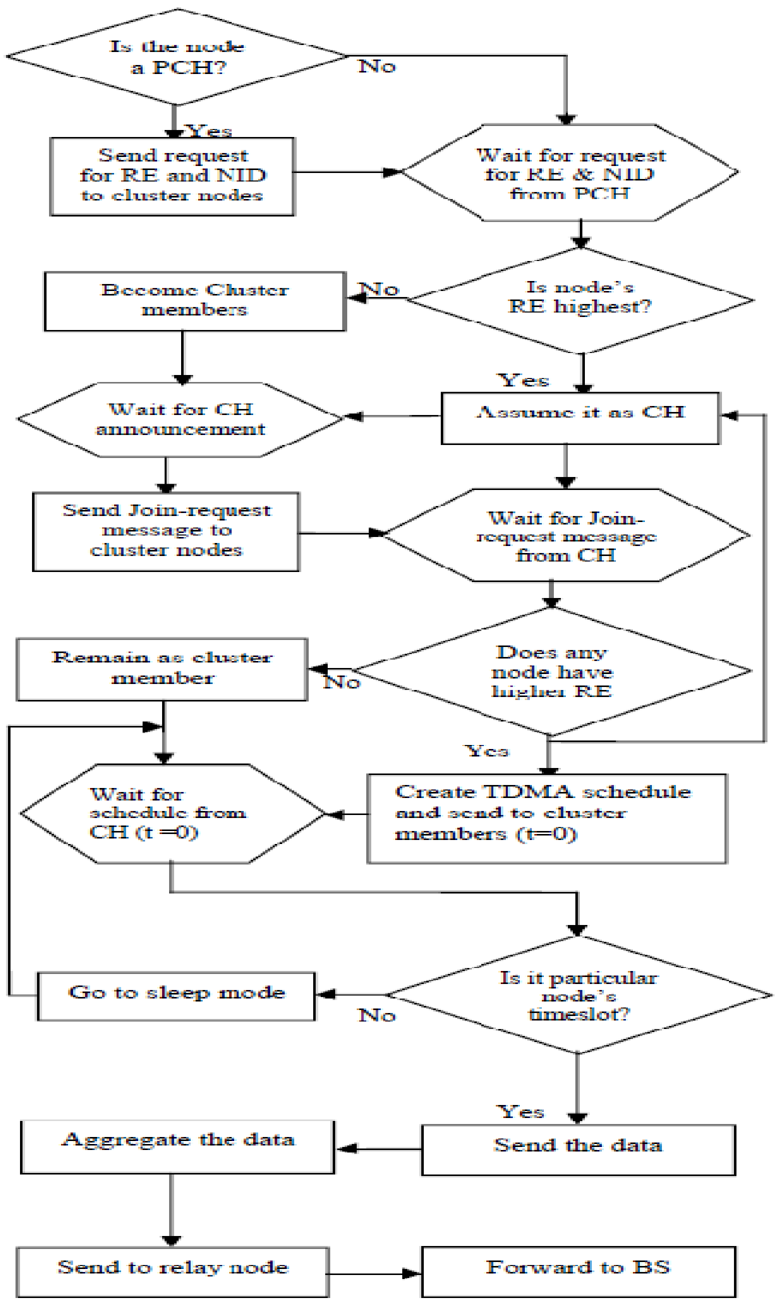

Fig. 4: Flowchart of VEEC

Stage IV– Cluster Head Re-election:

The CH calculates the lifetime of the member nodes based on their residual energies. The estimated lifetime $t_{LT(n)}$ of a node with NID represented by n, is expressed as the number of times it can be a CH. The CH uses the lifetime information to estimate the lifetime of the cluster. The lifetime of the cluster is estimated by the following equation,

$$t_{LT(c)} = min(t_{LT(1)}, t_{LT(2)}, ..., t_{LT(N)}) \tag{5}$$

where, N is the number of nodes in the network. The CH periodically compares its residual energy against the node's residual energies received. If any node is found with residual energy greater than that of CH, that particular node is re-elected as new CH. All wireless sensor nodes which have reached their own expected lifetimes will be considered themselves as dead and becomes idle. An idle node will not participate in any of the upcoming operations.

Simulation Study:

Simulation Settings:

The following assumptions are made in VEEC: (i) Sensor nodes, CH and BS are stationary. (ii) Relay nodes are highly rich in resources. (iii) Nodes use variable 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. (viii) Relay nodes solely perform routing of data to BS. All the simulations were carried using the network simulator NS-2. For energy consumption, the first-order radio model outlined in (Heinzelman *et al*., 2002) was employed.

For simulation, nodes were deployed randomly on the basis of the parameters outlined in table 1.The proposed distributed clustering algorithm is simulated with 20 nodes and at each time the energy utilization, node's residual energy, etc are recorded. Finally VEEC is compared with two existing algorithms LEACH and HEED based on the above recorded readings. A data collection process is said to be completed 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 100 x 100 meter^2. Once deployed the sensor nodes are assumed to be static. For simulation purpose the BS is placed at the center of the field but in real-world applications BS is located far away from the target environment. The BS contains sufficient energy and at any cost energy shortage does not occur.

Table 1: Simulation parameter setup

Parameter	Acronym	Values
Cluster topology (m)	C_t	100 x 100 m^2
Tx/Rx electronics constant Amplifier constant	$E_{tx/rx}$	50nJ/bit
Path-loss exponent	E_{amp}	10pJ/bit/m^2
CH energy threshold	P	2
Packet size	E_{th}	10^{-4}J
Packet rate	p	50 bytes
Number of nodes	b	1packet/s
Transmission range	N	20
Sensing range	R_{bc}	70m
Cluster range	R_{sense}	15m
	$R_{cluster}$	30m

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 its cluster nodes. The relay nodes are assumed to be in sleep mode unless CHs send the data to it. The main feature of the proposed algorithm is that, CHs does not send data directly to BS, instead they send to relay nodes which in turn forwards the data to BS to avoid energy wastage during long-haul communication.

Simulation Results:

The proposed algorithm VEEC is simulated and the results are recorded for average communication energy against time, normalized total system energy consumption and node death rate. These parameters are then compared with the two existing algorithms LEACH and HEED.

The relationship between average communication energy and time for LEACH, HEED and VEEC is shown in figure 5. From figure 5, the initial communication energy is less in VEEC (1.5 Joules) when compared with LEACH (2.2 Joules) and HEED (4.2 Joules). Also the average communication energy of VEEC is 1.58 Joules which is much lower with reference to the other two algorithms.

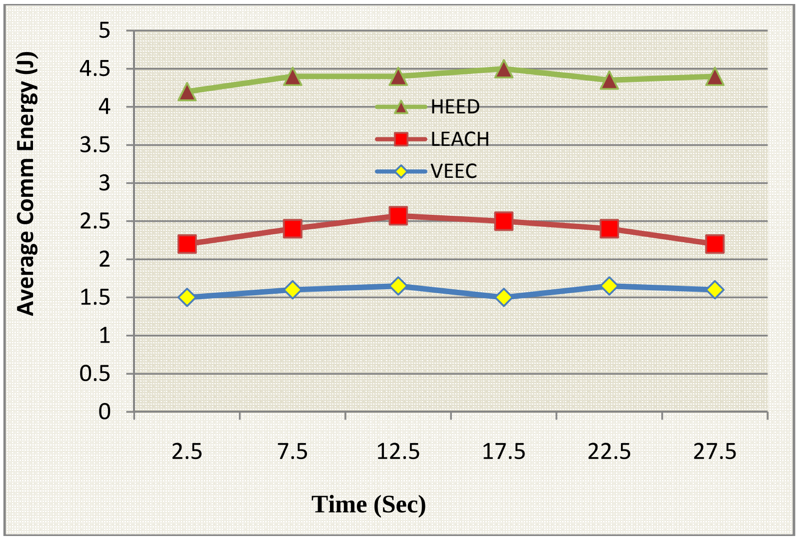

Fig. 5: Average communication energy against time (LEACH, HEED and VEEC)

VEEC shows good improvement in average communication energy when compared to LEACH and HEED. This is because LEACH and HEED uses more number of unnecessary communications between sensor nodes, CH and BS whereas VEEC avoids unnecessary communications.

The comparison of normalized total system energy consumption of LEACH, HEED and VEEC is shown in figure 6. LEACH and HEED has sharp decreasing slope. In figure 6, the initial energy consumption of LEACH and HEED is 10 Joules and the energy reduces to 0 Joule after 700 rounds, but in VEEC it happens only after 1300 rounds (Table 2).

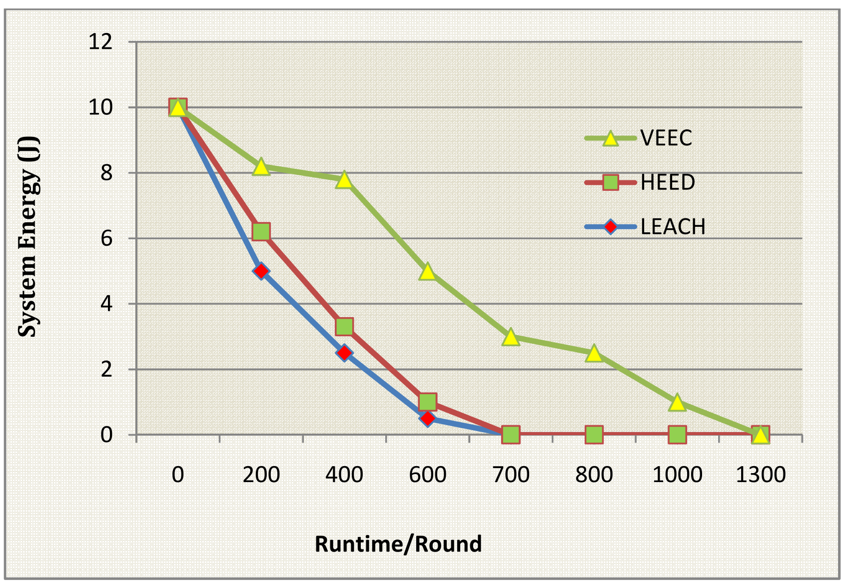

Fig. 6: Comparison of proposed protocol with LEACH and HEED (Normalized total system energy consumption)

Hence VEEC shows good improvement in total system energy consumption compared to LEACH and HEED. Simply, when LEACH and HEED runs out of half amount of their energies, VEEC runs out of only 25% of its energy. This is because of VEEC avoiding unnecessary communications during cluster-setup, with the help of relay nodes and by variable transmission power. Figure 7, depicts the node death rate i.e. the number of nodes die after particular round. For LEACH, all nodes are alive in 500 rounds, 1 node is alive in 600 rounds and in 700 rounds all nodes die. For HEED, all nodes are alive in 500 rounds, 5 nodes are alive in 600 rounds and in 700 rounds all nodes die. In VEEC, all nodes are alive till 700 rounds, 4 nodes are alive in 1000 rounds and in 1300 rounds every nodes die (Table 3). The proposed algorithm VEEC shows better improvement in lifetime compared to LEACH and HEED. This is because of the distinctive features applied for VEEC which were discussed in the preceding sections.

Table 2: Simulated values corresponding to total system energy and number of rounds

Runtime/Round	System Energy (J)		
	LEACH	HEED	VEEC
0	10	10	10
100	8	8.5	9.5
200	6	6	8.2
300	3.8	4.8	8.1
400	2.6	3.3	7.7
500	1.8	2	7
600	0.5	1	4.6
700	0	0	3
800	0	0	2.5
900	0	0	2
1000	0	0	1
1100	0	0	0.6
1200	0	0	0.4
1300	0	0	0

Table 3: Simulation results for number of nodes alive and number of rounds

Runtime/Round	Number of live nodes		
	LEACH	HEED	VEEC
500	20	20	20
550	10	13	20
590	5	7	20
595	3	6	20
600	1	5	20
700	0	0	20
750	0	0	15
800	0	0	10
850	0	0	8
900	0	0	7
950	0	0	5
1000	0	0	4
1100	0	0	3
1200	0	0	2
1300	0	0	0

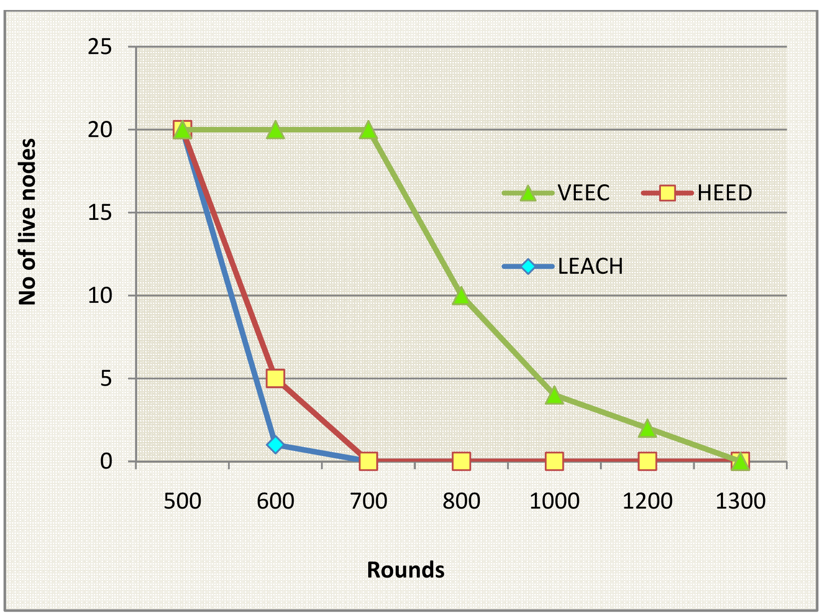

Fig. 7: Node death rate (LEACH, HEED and VEEC)

Discussions:

Average Communication Energy:

Average communication energy is the average of total energy spent during communication in the network over a stipulated interval of time. In LEACH, a sensor node communicates only with the nearest CH. When there is less number of CHs these CHs will be heavily loaded and the communication distance between cluster nodes and CH increases. The CH should announce its status to all the nodes in the network during cluster-setup phase. Hence, when more number of CHs are elected a node have to receive communication from many CHs in the network in order to select a nearest CH. All these communications will lead to increased communication energy for both CHs and cluster nodes.

Basically HEED was proposed to avoid random selection of CHs. Though LEACH was more energy efficient, the main drawback is the random selection of CH. In HEED, the selection of CH is based on residual energy and communication cost of the nodes. During the initialization phase, initial CH percentage will be given to the nodes. Every node tries to become a CH. There is no control for CH selection in the initialization phase and hence more energy is consumed even more than LEACH. Also in the repetition phase, until CH is found with least communication cost the process will be iterated. These iterations use many communications between the nodes and CH. These two phases makes the algorithm complicated in terms of communication energy from the beginning of cluster formation.

The proposed algorithm is based on the concept of one message per node for cluster-setup. A random node PCH sends one message for every cluster nodes requesting their NID and residual energies. These nodes on sending their details, the PCH compares the residual energy of the cluster nodes with its own residual energy and if any node has higher residual energy than that of PCH, that particular node is elected as CH. The characteristic feature of VEEC: the nodes having lower energy than CH never tries to become a CH, thereby unnecessary communications are avoided. In LEACH and HEED, much of the communication energy is wasted due to imbalance in number of CHs and by several phases for cluster-setup respectively. Also in VEEC, as the boundary of the cluster 'R' meters is known to the CH based on the beacon signal's RSSI and LQI, the cluster setup phase consumes only lesser communication energy.

Total System Energy Consumption:

It is the sum total of energy consumed during communication, processing, etc., which is the total energy consumed for entire clustering mechanism by the whole sensor network. As discussed in the previous section, 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. Due to two-hop structure of the network, a node far from CH will have to consume more energy than a node nearer to CH. This introduces an uneven distribution of energy among the cluster members, affecting the total system energy.

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 best communication cost. This is a peculiar drawback of HEED.

In the proposed algorithm, fewer communication energy is required which could be understood from the simulations. 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 with the property of relay nodes, much energy utilization for routing the aggregated data from CH to base station is avoided. But the two existing algorithms use direct communication between the CH and BS, which is generally long haul in nature. From the simulation, it is also clear that the slope of LEACH and HEED algorithms are maximum, hence consuming the available energy easily compared to VEEC. Also in the proposed algorithm, separation among the layers is optimized to use optimum power for each layer.

Node Death rate:

It is the measure of the number of nodes die over a time period, from the initiation 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 increased data collection. This increases the node death rate. The proposed algorithm uses a limited data collection process by using limited messages in cluster-setup phase. In all the three algorithms, the cluster size is variable but in order to compensate this, the proposed algorithm uses variable transmission power. Also the proposed algorithm has an excellent control over the number of connections between the cluster nodes, CH and relay nodes. In LEACH and HEED, there is no control over the number of connections, which increases the data collection time, thereby increasing data rate and node death rate. From the simulation, the proposed algorithm shows only half of the death rate in comparison with LEACH and HEED.

Conclusion:

In this paper a well distributed clustering algorithm, variable power energy efficient clustering algorithm has been proposed. Based on single message for cluster-setup, variable transmission power and relay nodes, the algorithm VEEC has been formulated to form efficient clusters in a wireless sensor network. The algorithm is analyzed and the performances are compared with the two existing clustering algorithms LEACH and HEED. It is seen that the proposed distributed clustering algorithm has shown much improvement in communication energy over the two well evaluated algorithms. The performance of the proposed algorithm shows 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.

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