A VARIABLE POWER BASED DISTRIBUTED CLUSTERING METHODOLOGY FOR CONNECTING SPARSE WIRELESS SENSOR NETWORK FIELDS

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Abstract
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 distributed clustering methodology, the hybrid energy efficient clustering algorithm (HEECA) has been investigated. The proposed methodology is a well-distributed and energy-efficient clustering algorithm which employs three novel techniques: zone based transmission power (ZBTP), routing using distributed relay nodes (DRN) and rapid cluster formation (RCF). The proposed methodology is compared with the two well-evaluated existing distributed clustering algorithms O-LEACH and hybrid energy efficient distributed clustering (HEED). The proposed methodology shows an improvement in residual energy, throughput and energy efficiency of the wireless sensor system. The clustering process could be effectively controlled, thereby the number of cluster head selection and the number of packets delivered to the base station shall be carried out effectively. Ultimately, the overall lifetime of the wireless sensor network is much improved. The distributed relay nodes employed in the proposed methodology could effectively connect two separate wireless sensor network fields with reduced packet loss.

Keywords: Wireless sensor network (WSN), distributed clustering algorithm, coverage based clustering, energy efficiency, network lifetime.

1. INTRODUCTION

A wireless sensor node consists of low power processor, tiny memory, radio frequency module, sensing devices and limited powered batteries. Much of the energy consumption takes place during wireless communication. An efficient way to reduce energy usage is to group the sensor nodes into several clusters and each individual cluster has a cluster head. The cluster head forwards the aggregated data to the base station. In distributed clustering, the cluster head changes from one node to another node based on some parameters. In most of the distributed clustering mechanisms, every sensor nodes use same amount of power for communicating with the cluster head and base station. Since the nodes use different power levels for communication, the proposed methodology is called as variable power distributed clustering methodology [1-11].

In this paper, a distributed clustering algorithm, the variable power energy efficient clustering (VEEC) has been proposed which is based on variable transmission power, relay nodes and single message per node for cluster-setup. The prime objective of the proposed algorithm is to achieve energy efficiency and extended network lifetime. The performances of the proposed algorithm have been evaluated against two existing algorithms LEACH and HEED.

2. RELATED WORKS IN CLUSTERING

The distributed clustering methodology EEHC is a randomized clustering algorithm for 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 centre. LCA was mainly implemented to avoid the communication collisions among the nodes by using a TDMA time-slot. The revised version of LCA [12], the LCA2 was implemented to decrease the number of nodes compared to the original LCA algorithm. With an objective to form overlapping clusters with maximum cluster diameter of two hops, CLUBS algorithm has been implemented in wireless sensor networks. FLOC achieves re-clustering in constant time in a local manner in large scale network and exhibits double-band nature of wireless radio-model for communication [24-33].

Ye et al (2005) proposed Energy Efficient Clustering Scheme (EECS) which is based on the assumption that every cluster heads 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. Ye et al (2005) proposed Energy Efficient Unequal Clustering mechanism (EEUC) for uniform energy consumption within the network. It forms unequal clusters [13-23], with an assumption that each cluster can have variable sizes. Based on the residual energy of the sensor nodes, connectivity and a unique node identifier, the cluster head selection is accomplished in Distributed Efficient Clustering Approach (DECA) as formulated by (Yu et al 2006).

The distributed clustering algorithms which have fallen into the research interest are LEACH and HEED. These algorithms organize the networks with different network topologies.

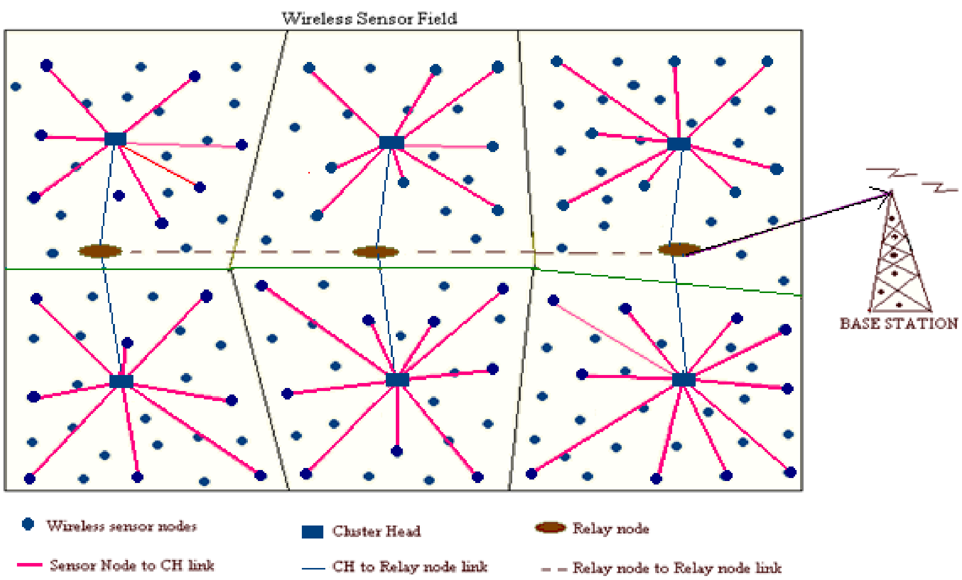

Figure 1: Articulation of VEEC Clustering Methodology

3. THE MODEL OF VEEC

The proposed algorithm 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 aggregates 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. Figure 1 shows the general articulation of the proposed VEEC methodology. Compared to the existing algorithms, VEEC has three distinguishing features: First, in many clustering algorithms CH forwards the data to BS directly, which leads to energy wastage but in VEEC, CHs does not forward the data to BS. Instead CH forwards data packets to relay nodes and these rich-resourced relay nodes routes data to BS thereby considerable energy usage 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 further reduce considerable energy usage. Third, the cluster head sends one message for setting up the cluster but many existing algorithms use several messages for cluster-setup.

In a network of N nodes, each node is assigned with 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). In the proposed methodology, a layer is formed on the basis of distance between the sensor node and the cluster head. 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 layer number. 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 reduction.

A relay node is 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. 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.

The proposed algorithm VEEC uses a single message for cluster-setup. Initially in each cluster, the nodes with relatively higher residual energy assume 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 then compares its residual energy with those of the 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 time-slot, unnecessary transmissions are avoided thereby reducing power usage and prolonging the network lifetime. In VEEC, the node with highest residual energy has the maximum probability of becoming a CH. Initially the 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 then 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 the interest of other nodes in becoming a CH. Nodes receiving this message will stop their action and joins that CH. The CH aggregates all the incoming data packets together and the aggregated data is forwarded to the 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 will be correlated. 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 layers starting from the BS. The relay nodes in the layer nearer to the BS need to relay more packets and hence more number of relay nodes has to be placed in the layer nearer to BS. The layer farther from BS requires fewer number of relay 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.

4. SIMULATION STUDY

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 should 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 NS-2. 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, the performance of VEEC is compared with the 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 of 500m x 500m. 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. The sensor nodes have limited energy with initial energy of 1Joule. 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 the relay nodes which in turn forward the data to BS to avoid energy wastage during long-haul communication.

The proposed algorithm VEEC is simulated and the results are recorded for average communication energy, normalized total system energy consumption and network lifetime. These parameters are then compared with the two existing algorithms LEACH and HEED. Figure 2 demonstrates the simulation results for average communication energy for particular rounds in LEACH, HEED and VEEC. Initially in 100 rounds, the average communication energy is 0.13 Joules for HEED, 0.09 Joules for LEACH and 0.04 Joules for VEEC. Similarly in 3000 rounds, the average communication energy is 0.13 Joules for HEED, 0.09 Joules for LEACH and 0.04 Joules for VEEC. VEEC shows an improvement of 57.02% when compared to LEACH and 67.50% when compared to HEED in terms of average communication energy. Thus it could be clearly seen that, from the beginning till the last round the average communication energy is very less in VEEC when compared to LEACH and HEED. This is mainly because of the modifications that are adopted at the level of clustering in the proposed methodology

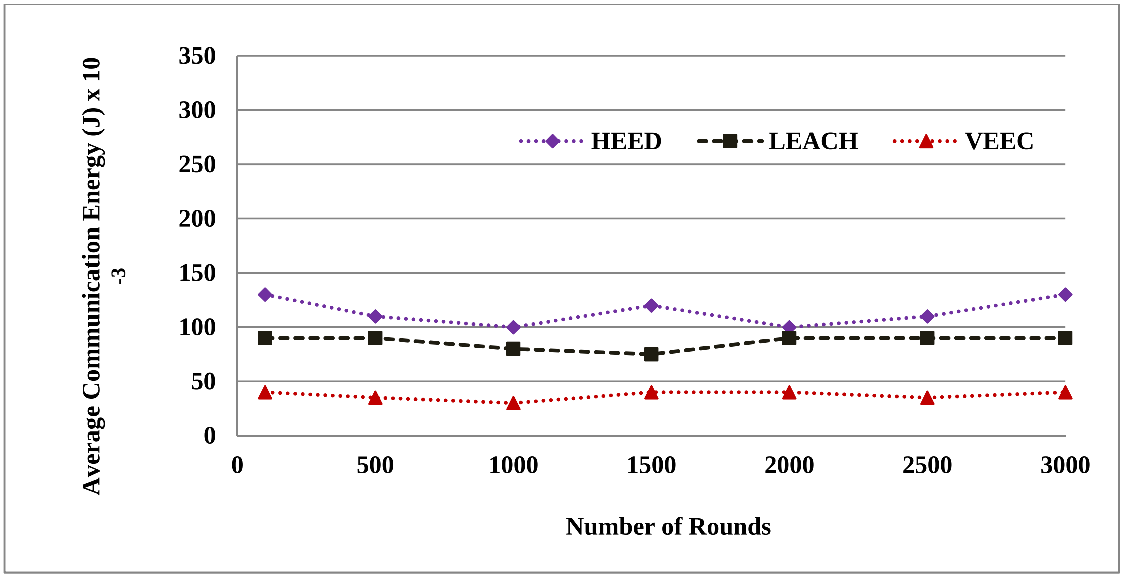

Figure 2: Average Communication Energy versus Number of Rounds (LEACH, HEED and VEEC)

Figure 3 represents the normalized total system energy consumption for all the three algorithms. Initially in 100 rounds, the total system energy consumption is 0.3 Joules for HEED, 0.22 Joules for LEACH and 0.09 Joules for VEEC. Also in 3000 rounds, the total system energy consumption is 0.18 Joules for HEED, 0.135 Joules for LEACH and 0.09 Joules for VEEC. The proposed algorithm VEEC shows 40.18% improvement in system energy consumption over LEACH and 56.77% improvement in system energy consumption when compared to HEED. In case of LEACH and HEED, the resulting curve is steeper with increased slope which is generally not preferable. But in VEEC, the slope of the curve is almost minimum. Thus it could be clearly seen that, VEEC shows reduction in total system energy consumption compared to LEACH and HEED. This is because of VEEC avoiding unnecessary communications during cluster-setup, with the help of relay nodes and by variable transmission power.

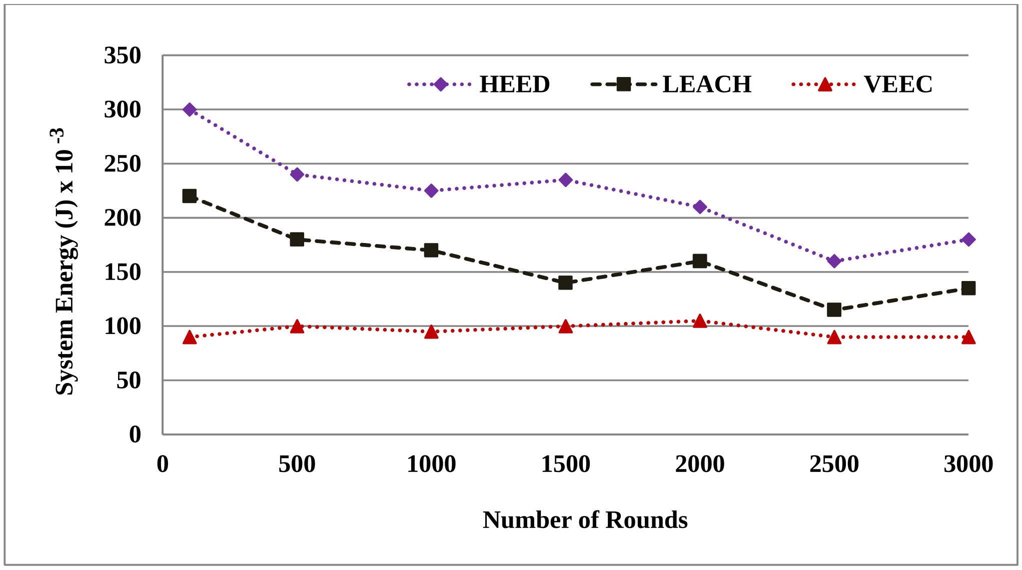

Figure 3: Comparison of proposed methodology with LEACH and HEED (Normalized Total System Energy Consumption)

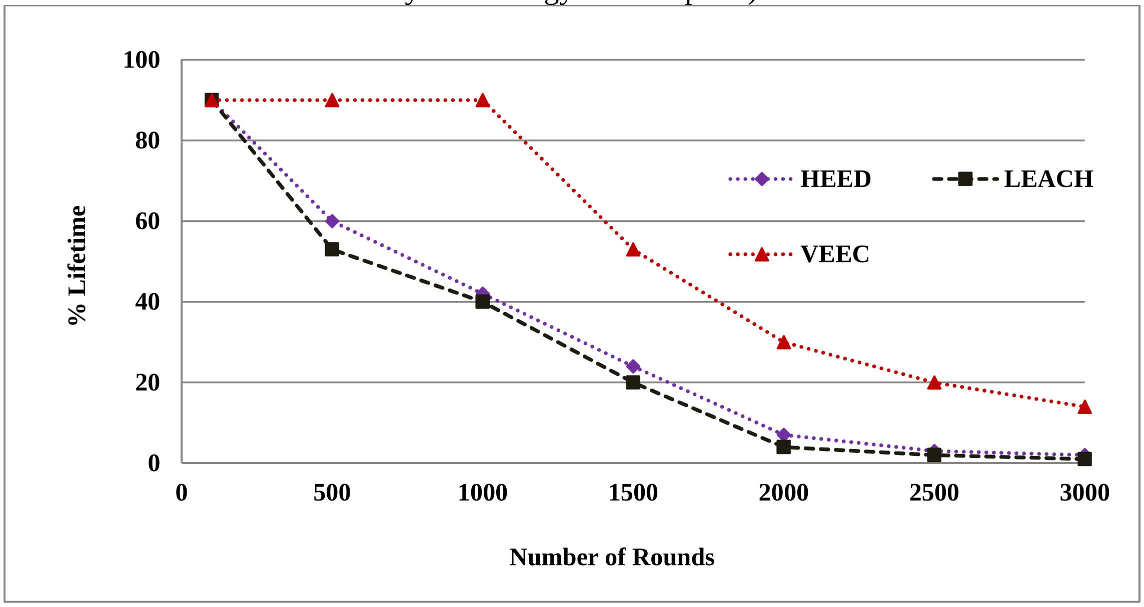

Figure 4: Lifetime Comparison of LEACH, HEED and VEEC

Figure 4 depicts the network lifetime for particular number of rounds for all the three algorithms. Initially in 100 rounds, 90% of the sensor nodes are alive for all the three algorithms. In 1000 rounds, the percentage lifetime of VEEC is 90% but in case of LEACH and HEED the percentage lifetimes are reduced to 40% and 42% respectively. In 2000 rounds, almost all the nodes die for the two existing algorithms, but VEEC shows a great improvement in lifetime till the end of the process. A moderate difference of 25.57% and 23.43% is seen in VEEC with respect to LEACH and HEED in terms of average network lifetime. The proposed algorithm VEEC shows better improvement in network lifetime when compared to LEACH and HEED. This is because of the distinctive features applied for VEEC which have been discussed in the preceding sections. This evidently shows that VEEC based clustering methodology could be effectively employed for wireless sensor network systems where network lifetime and energy efficiency is a primary criterion.

Average communication energy is the average of total energy spent during communication in the network over a stipulated interval of time or after particular number of rounds. 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. When more number of CHs are elected, a node have to receive communication from many CHs in the network in order to select the nearest CH. All these communications will lead to increased communication energy by both CHs and cluster nodes.

Basically HEED was proposed to avoid the random selection of CHs. Though LEACH was more energy efficient, the main drawback is the random selection of cluster head. In HEED, the selection of cluster head is on the basis of residual energy and the communication cost of the sensor 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 that of LEACH. Also in the repetition phase, until CH is found with least communication cost the process will be iterated. These iterations use more communications between the nodes and CH. These two phases make the algorithm complicated in terms of communication energy from the beginning of cluster formation.

The proposed algorithm is based on the concept of single message per node for cluster-setup. A random PCH node 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 is that the nodes having lower energy than CH never tries to become a CH, thereby unnecessary communications are avoided. In LEACH and HEED, more energy is wasted during communication due to imbalance in the number of CHs and due to several phases for cluster-setup. 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 section 5.6.1, LEACH use 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 farther 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 mainly on the basis of 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 repetition phase, more number of iterations are carried out in order to find a node with best communication cost. This is a peculiar drawback of HEED.

In the proposed algorithm, lesser 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, more 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 when compared to VEEC. Also in the proposed algorithm, separation among the layers is optimized to use optimum power for each layer.

Network lifetime is basically related to node death rate. Node death rate 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 condition prevails also in HEED due to increased data collection. This increases the node death rate. The proposed algorithm uses 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. The proposed algorithm shows prolonged network lifetime when compared to LEACH and HEED to a great extent.

5. CONCLUSION

In this paper a well distributed clustering algorithm VEEC 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 wireless sensor network. The algorithm is analysed and the performances are compared with the two existing clustering algorithms LEACH and HEED. The proposed distributed clustering algorithm depicts much reduction in average communication energy when compared to the two existing clustering algorithms. The performance of the proposed algorithm shows a drastic reduction in the total system energy consumption. Nevertheless, the proposed algorithm VEEC greatly prolongs the overall network lifetime of the wireless sensor network system.

REFERENCES

1. 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.
2. 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.
3. 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.
4. Gajendran E., "Biosensing with U-Shaped Fiber Smeared With Gold Nanoparticles", International Journal of Multidisciplinary Research and Modern Education, Volume 3, Issue 1, Pages 410-413, May 2017.
5. Gajendran E., "Randomized Cluster Head Selection Strategy for Dense Wireless Sensor Networks", International Journal of Multidisciplinary Research and Modern Education, Volume 3, Issue 1, Pages 414-420, May 2017.
6. Pradeep M., "Distributed Clustering Approach for Wireless Sensor Networks Based on Hybrid Concept", Star International Journal, Volume 5, Issue 3(1), Pages 01-06, March 2017.
7. Pradeep M., "Analysis of Large Scale Wireless Sensor Network for Energy Efficiency", Star International Journal, Volume 5, Issue 3(1), Pages 07-11, March 2017.

8. Pradeep M., "An Analysis of Smart Irrigation System Using Wireless Sensor Network", Star International Journal, Volume 5, Issue 3(1), Pages 12-17, March 2017.
9. Pradeep M., "Parametric Analysis of Varying Greenhouse Gases Using Wireless Sensor Network", Star International Journal, Volume 5, Issue 3(1), Pages 08-23, March 2017.
10. N.Balakumar, "A Research on Dissimilar Categorization of Basic Electrical Generator", OMICS Journal of Electrical & Electronic Systems, Volume 6, Issue 1, February 2017.
11. N.Balakumar, "Energy Efficient Enhancement and Initial Cost Saving Mechanisms for Petrochemical Manufacturing Industrial", OMICS Journal of Petroleum & Environmental Biotechnology, Volume 8, Issue 1, February 2017.
12. N.Balakumar and A.Johnson Antony, "Evolving Constraints in Military Applications using Wireless Sensor Networks", International Journal of Advanced Research in Mechanical Engineering & Technology, Volume 2, Issue 4, pp.19-22, Oct. - Dec. 2016.
13. N.Balakumar and A.Johnson Antony, "Mechanism in Improving the Performance of Disabled using Embedded Systems", International Journal of Advanced Research in Mechanical Engineering & Technology, Volume 2, Issue 4, pp.23-28, Oct. - Dec. 2016.
14. N.Balakumar and A.Johnson Antony, "Modern Techniques to Attain Smart Vehicular Schemes using Embedded Systems", International Journal of Advanced Research in Mechanical Engineering & Technology, Volume 2, Issue 4, pp.34-38, Oct. - Dec. 2016.
15. N.Balakumar and A.Johnson Antony, "An Evaluation of Greenhouse Parameters Using Embedded Sensor Networks", International Journal of Advanced Research in Mechanical Engineering & Technology, Volume 2, Issue 4, pp.39-44, Oct. - Dec. 2016.
16. Pradeep M., "Monitoring the Activities of Human Heart: A Brief Assessment", Asian Journal of Applied Science and Technology (AJAST), Volume 1, Issue 1, Pages 36-37, February 2017.
17. Pradeep M., "Technical Issues while Forming Clusters in a Wireless Sensor Network", Asian Journal of Applied Science and Technology (AJAST), Volume 1, Issue 1, Pages 34-35, February 2017.
18. 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.
19. 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, pp. 177-184, January 2017.
20. N.Balakumar and A.Johnson Antony, "Wireless Sensor Network Based Smart Environment Applications", International Journal of Innovative Research in Technology, Volume 3, Issue 8, pp.153-162, January 2017.
21. 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.
22. 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.
23. 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.
24. A.Johnson Antony, "An Illustration of Optic Sensors in Recent Research Domains", International Journal of Innovative Research in Technology, Volume 3, Issue 8, pp. 169-176, January 2017.

25. A.Johnson Antony, "Management Strategies for Voice Based Communication towards Emerging Networks", International Journal of Innovative Research in Technology, Volume 3, Issue 8, pp. 185-190, January 2017.
26. 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.
27. 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.
28. 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.
29. 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.
30. Gajendran E., "Systematic Analysis of Congestion Control in WDM Mesh Networks", Asian Journal of Applied Science and Technology (AJAST), Volume 1, Issue 1, pp. 01-04, February 2017.
31. Gajendran E., "Embedding Hierarchical Concept of Clustering for Large Scale Sensor Network", Asian Journal of Applied Science and Technology (AJAST), Volume 1, Issue 1, pp. 05-08, February 2017.
32. 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.
33. 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.