Abstract — Energy efficiency is one of the most important challenges for Wireless Sensor Networks (WSNs). This is due to the fact that sensor nodes have limited energy capacity. Therefore, the energy of sensor nodes has to be efficiently managed to provide longer lifetime for the network. To reduce energy consumption in WSNs, a modified Energy Efficient Clustering with Splitting and Merging (EECSM) for WSNs using Cluster-Head Handover Mechanism was implemented in this research. The modified model used information of the residual energy of sensor nodes to select backup Cluster Heads (CHs) while maintaining a suitable CH handover threshold to minimize energy consumption in the network. The backup CHs take over the responsibilities of the CHs once the handover threshold is reached. The modified model was validated in terms of network lifetime and residual energy ratio with EECSM using MATLAB R2013a. Average improvements of 7.5% and 50.7% were achieved for the network lifetime and residual energy ratio respectively which indicates a significant reduction in energy consumption of the network nodes.

Keywords — Clustering, Energy-Efficiency, Handover, Lifetime, Wireless Sensor Network

1 INTRODUCTION

Wireless sensor networks have recently emerged as an important means to study and interact with the physical world (Oreku & Pazynyuk, 2016). The recent technological advances have made it possible to deploy small, low power, low-bandwidth, and multi-functional wireless sensor nodes to monitor and report conditions and events in their local environments (Ali et al., 2015). A large collection of these sensor nodes can thus form a wireless sensor network in an ad-hoc manner, creating new types of information system. Sensor nodes are usually deployed randomly in the field and form an ad-hoc sensor network to fulfill certain tasks. There is usually no infrastructure support for sensor networks (Liu & Ning, 2007). Every sensor node in a sensor network has one or a few sensing components to sense conditions such as temperature, humidity, pressure, etc. from its immediate surroundings, a processing component to carry out simple computation on the raw data, and a communication component to communicate with its neighbor nodes (Akyildiz et al., 2002).

The critical issue in the design of wireless sensor networks is how to effectively utilize the limited Quality of Service (QoS) parameters. The most basic QoS parameters of sensor networks are bandwidth and energy (Talikoti & Jayashree, 2012). The efficient utilization of these resources has posed numerous challenges because the power supply unit of a sensor node is based on an energy-limited battery. Most techniques used as solutions for these networks are aimed at minimizing the energy consumption in order to provide longer network lifetime. Amongst these techniques, the cluster based routing technique has proven to be the most energy efficient and involves dividing node deployment area into smaller regions called clusters (Lee & Lee, 2013). The clustering concept offers tremendous benefits for WSNs because it reduces the size of the routing table, conserves communication bandwidth, prolongs network lifetime, decreases the redundancy of data packets, reduces the rate of energy consumption, etc. (Wajgi & Thakur, 2012).

Also, a sensor network should have self-organizing functionalities since sensor nodes may be required to be placed in strategic locations that may not be easily accessible except by using airplanes. A self-organizing network should be able to generate adequate formations depending on the current situation in terms of environmental circumstances etc. (Zeb et al., 2015).

To increase the lifetime of WSNs, EECSM was developed by (Lee & Lee, 2013) and incorporated a self-organized clustering technique with splitting and merging. However, EECSM has been modified in this work to further increase the lifetime of WSNs by incorporating a backup CH and a CH handover mechanism to reduce the frequent selection of CHs after each event of data transmission. This approach ensures a reduction in the energy consumed for the transmission and reception of control packets in the network. The difference in the modified model (mEECSM):

1. In the modified model, a suitable CH handover threshold was incorporated to induce handing over to the backup CH when reached. This helped to reduce frequent selection of next CH and re-clustering which involves control packets exchange between the next CH and the Cluster Members (CMs).

2. In EECSM, the backup CH is selected and activated only when a breakdown of the CH occurs in the network. In the modified, the backup CH becomes the CH when the current CH handover threshold is reached and during a sudden breakdown of the CH.

3. In EECSM, the backup CH is selected by the CMs. This involves the exchange of control signal packets among the CMs to select the node with the highest energy level which is then activated as the backup CH. In the modified model, a backup CH is selected only by the CH. This reduces the excess control signal packets exchange among CMs when selecting CHs for every transmission round. This saves energy.

4. In the modified model, a cluster is further split until its number of nodes is less than the splitting threshold before the CH starts transmitting to the Base Station (BS). This helps to reduce the initial loading of the first and second CHs for a large number of node deployment.
1.1 REVIEW OF RELATED WORKS

An improved clustering algorithm based on Low Energy Adaptive Clustering Hierarchy (LEACH), that considered node’s residual energy and location information in selecting CHs was proposed by Liao and Zhu, (2013). Normal nodes selected the optimal CH based on some cost function which included distances from the base station, energy level and location information. However, getting location information from CHs consumed energy which was a limitation to the work. An Energy Efficient Self-organized Clustering with Splitting and Merging (EECSM) for WSNs was implemented by Lee and Lee, (2013). EECSM performed splitting and merging of clusters using information of the energy state of sensor nodes to select a CH and maintain load balancing. Simulation results showed that EECSM significantly outperformed Hybrid Energy Efficient Distributed Clustering (HEED).

A cluster-based Route Optimization and Load-balancing (ROL) protocol aimed at prolonging network lifetime, providing timely message delivery, and improving network robustness was developed by Hammoudeh and Newman (2013). Nutrient-flow-based Distributed Clustering (NDC), an algorithm for achieving load balancing by equalizing the diameter and the membership of clusters was also incorporated. ROL improved on the robustness of LEACH by ensuring that each node learned multiple paths to its CH. Energy expenditure was reduced by shortening the distance between nodes and CHs. A global power management approach for energy harvesting sensor nodes that utilized a joint duty-cycle optimization and transmission power control was implemented by Castagnetti et al., (2014). Duty-cycle management, dealt with the control of task activation rate where a node followed a sleep-wake up cycle in order to balance the energy that is harvested and the energy that was consumed. Transmission power control dealt with the RF transmission power adjustment of the node for quality packet reception at the BS.

A Novel Cluster Arrangement Energy Efficient Routing Protocol (CAERP) for WSNs was employed by Vijayan and Raaza, (2016). The protocol consisted of a cluster head selection algorithm, a cluster formation scheme and a routing algorithm for data transmission between cluster heads and the base station. The base station utilized the global information of the network for cluster head selection and cluster formation which helped to produce better clusters that required less energy for data transmission. A distributed algorithm for Ad-hoc network partitioning based on Voronoi Tessellation was proposed by Pietrabissa et al., (2016). A data sink node selection algorithm for multi-hop WSNs with multiple data sink nodes was presented. For energy-saving considerations, a distributed and iterative algorithm which periodically re-assigned the data sink roles to selected WSN nodes was designed. The algorithm dealt with spatial distribution of the data sink nodes in the network to achieve energy efficiency using Voronoi Tessellation as well as Centroidal Voronoid Tessellation. Due to the inapplicability of LEACH protocol for large-scale sensor network and uneven energy consumption, a Distributed Self-organizing Clustering Routing (DSCR) protocol for large-scale sensor network was proposed by Ou et al., (2017). The network routing was divided into two cluster levels: parent cluster and sub-cluster. The CM nodes in the sub-clusters transfer data to their CHs using multi-hop routing in their respective TDMA slots. The data between the CHs are aggregated and uploaded to the parent cluster to form the parent cluster structure. A network load balancing algorithm for grid-based clustering was designed by Pitke et al., (2017). Merging and splitting of clusters was devised for sparse and dense clusters respectively and cross clustering was applied for averagely dense clusters. The decision of cluster members to join adjoining cluster depended on their relative distance from the current CH and adjoining CH. The BS divided the deployment area into clusters, selected CH nodes and broadcasted this information to the nodes.

A novel Cooperative Data Exchange (CDE) scheme using Instantly Decodable Network Coding (IDNC) across sensor nodes was proposed by Zayene et al., (2017). An effective distributed schemes that enabled nodes’ cooperation in recovering sensed data was achieved using cooperative game theory in partition form. A distributed merge-and-split algorithm was developed to form dynamic coalitions that maximized the energy consumed and IDNC delay experienced by all sensor nodes. The proposed algorithm enabled nodes to self-organize into stable clustered network structure where all sensors do not have incentives to change the cluster he is part of. A comprehensive study on the design of an Energy-Aware Mechanism for Lifetime Improvement of WSNs was carried out by Jabbar et al., (2018). An Extended-Multilayer Cluster Designing Algorithm (EMCDA) for large networks was proposed. The proposed protocol incorporated mechanism for; time slot allocation, minimizing the CH competition candidates, and determining the number of nodes to a CH. These incorporations in MCDA resulted in minimized transmissions, reduced unnecessary response of transmissions, and brought about near equal size and equal load clusters.

It is evident from the literature reviewed that one of the ways of improving the Quality of Service (QoS) of wireless sensor networks is by improving the network availability through reduction of energy consumption. This has been given significant research attention leading to the development of improved algorithms and routing protocols in this area. However, these algorithms could not clearly define the number of nodes to form a cluster except the work of Lee and Lee (2013). Also, in most of these algorithms every node in the network had to communicate with the base station which is far away in order to select a new CH. This process consumed substantial amount of energy. This work is a modification of Lee and Lee (2013) model, EECSM. Development of an improved model was achieved by reducing the frequent selection of CHs which took place for every period. This was done by incorporating a CH backup mechanism to reduce the energy consumed in frequent transmission and reception of control packets in the network.
2 SYSTEM MODEL AND ASSUMPTIONS
In this section, concepts fundamental to this research work are reviewed. These include models, principles and their mathematical equations as well as techniques and algorithms relevant to this research work.

2.1 RADIO ENERGY DISSIPATION MODEL
It is assumed that constant amount of energy is consumed in the internal processing of a packet, whereas the energy consumed in amplifying the signal to achieve acceptable signal-to-noise ratio at a receiver is proportional to the square of the distance between the transmitter and the intended receiver (Patel et al., 2004). The energy required for a node to transmit a packet of length k bits over a distance d is (Liao & Zhu, 2013):

\[ E_{TX}(k, d) = (E_{elec} + \varepsilon_{amp} d^2) k \]

(1)

While the energy consumed in Joules (J) at the receiving node is (Hammoudeh & Newman, 2013):

\[ E_{RX}(k) = E_{elec} \times k \]

(2)

where:

- \( E_{TX}(k, d) \) is the energy consumed in transmitting k bits data to a node at a distance of d.
- \( E_{RX}(k) \) is the energy consumed in receiving k bits data.
- \( E_{elec} \) is the per bit energy consumption for the transmitter and receiver circuitry.
- \( \varepsilon_{amp} \) is the per bit energy consumption by the node’s amplifier.

2.2 NETWORK LIFETIME AND RESIDUAL ENERGY RATIO
Network lifetime is the period until a certain number of sensor nodes (e.g., 30 sensor nodes) are all discharged of their energy (Lee & Lee, 2013). A period is a cycle of the process of collecting data packets from all the CMs by the CH and transmitting the collected data to the BS. The number of repeated periods during a data transmission phase is the clustering round (Lee & Lee, 2013).

The residual energy level is defined as the average of the remaining energy level of the sensor nodes at the end of each simulation experiment (Torkestani, 2015). The residual energy of a node, \( ER(t) \) in time t, is defined by omitting consumed energy, \( E_{cd}(t) \) from the initial battery power, \( E_i(t) \) (Kamyabpour & Hoang, 2011):

\[ ER(t) = E_i(t) - E_{cd}(t) \]

(3)

Also, the percentage ratio of the residual energy of sensor node, \( ER_i(t) \) is calculated as follows:

\[ ER_i(t) = \frac{\sum E_{ci}}{E_{ci}} \times 100 \]

(4)

where:

- \( E_{ci} \) and \( E_{ci} \), are respectively the current and initial energies of a node.
- \( n \) is the number of nodes in the network.

2.3 VARIOUS SIGNAL PACKETS
CH-signal packets - This is the signal that is broadcasted by the CH to announce its presence in the network. When this signal is directed to a particular node (using a node ID), that node becomes the CH.

CH-failure signal packets - This is the signal that is transmitted to activate a backup CH when the CH fails in the network.

Backup CH-signal packets - This is the signal transmitted by the CH to a particular CM which becomes the backup CH and is put to sleep.

Undecided state-signal packets - The signal packet that is transmitted by the undecided state nodes to request for CH-signal packets is called “undecided state-signal”. This signal enables the undecided state nodes to choose a CH.

Request to-join-signal packets - This is the signal that is transmitted by the undecided state node requesting to connect to a particular CH.

Acknowledgement (ACK) - This is the reply received by the undecided state node from a CH after sending a request to join signal packets to that CH.

2.4 CH HANDOVER MECHANISM
This is a technique through which a CH hands over its responsibilities to the backup CH when its energy level reaches a predefined threshold. The node with the highest energy level is selected as the CH. The selected CH request the CMs to send information about their residual energy levels. This received information is used by the CH to select a node with the highest energy level as its backup CH which is put to sleep. When the residual energy level of the CH reaches a predefined threshold after many periods, it hands over its responsibilities to the backup CH. All sensor nodes in the network only participate in CH selection at initial deployment after which the CH decides its backup CH which later becomes the CH.

A CH-handover threshold is set for the CHs. Once the CH handover threshold is reached, the CH transmits ‘CH-failure signal’ to the backup CH which then acts as the CH, broadcast ‘CH-signal’ and selects its own backup CH. The CH that reached its set energy threshold then becomes a CM. This technique was adopted to limits the frequent selection of CHs after every transmitted data and thus, a reduction in the number of control messages in the network which in turns, improved the network lifetime.

2.5 PARAMETERS USED IN THE SIMULATION
All assumptions, parameters, and terms considered during simulation are described below. These parameters were also considered by (Lee & Lee, 2013).

1. The locations of all sensor nodes and the BS are fixed.
2. The deployment of sensor nodes uses random distribution.
3. The number of sensor nodes is 100.
4. The size of the sensor field is 50m by 50m
5. The location of the BS is x-axis: 25m, y-axis: 150m
6. The broadcasting range is set to 10m.
7. The data packet size is 1,000 bits, and the signal packet size is 50 bits.

http://dx.doi.org/10.46792/fuoyejet.v4i1.329
8. All sensor nodes have an initial energy of 0.5 J.
9. The comparison test utilized the average performance of 10 different deployments of sensor nodes in the sensor fields.
10. The network is assumed to have failed when more than 30% of the sensor nodes are discharged of energy.
11. Cluster heads directly transmit the data packets received to the BS.
12. The per bit energy consumption for transmitter and receiver circuitry ($E_{\text{elec}}$) and the per bit energy consumption by the node’s amplifier ($E_{\text{amp}}$) is assumed as 50 nJ/bit and 100 pJ/bit/m² respectively.
13. The splitting cluster step is initiated when the number of nodes in a cluster is above 45. When it’s less than 20, the merging cluster step is initiated.

3 EXPERIMENTAL METHODOLOGY
This section describes the detailed procedure carried out in performing and modeling the: clustering, cluster merging, backup CH selection, CH handover mechanism, data transmission phase in accordance with the flow chart of figure 1.

![Flowchart for the Modified Model](image)

When the sensor nodes are first scattered in the sensor field, there are no CHs. Every node in the network competes for the position of a CH by broadcasting information about its “sensor ID” and “energy level” to neighbor nodes within twice its broadcasting range of 10 meters. These nodes are called the undecided state nodes. Also, a sensor node that has acted as a CH becomes an undecided state node. The step by step process is thus explained:

**Broadcasting Step**
(For all sensor nodes)
1. Broadcast an “undecided state-signal” packet within twice the broadcasting range.
2. Receive the undecided state-signal packets and count the number of received signal packets from other nodes.
3. Compare the number of received signal packets. Any node that received number of signal packets higher than its own stops competing for the position of the CH. If one’s value is Max, the sensor node becomes a CH.
4. The CH broadcast a “CH-signal” packet to the entire sensor field
5. CMs transmit “request to join signal” packet to the CH
6. CH sends ACK, and a cluster is formed

**Splitting cluster step**
(For each CH)
1. The CH counts the number of CMs and if the number of CMs ≥ Splitting threshold,
2. The CH splits the network by deciding the First and Second CHs. That is the first and second CMs having maximum residual energy of the cluster.
3. The CH transmits a CH-signal to the First and second CHs and become an ordinary node with an undecided state
4. The new CHs broadcast a CH-signal packet to the entire sensor field.
5. CMs decide their own CH, by finding the closest CH
6. CMs transmit “request to join signal” packet to the closest CH
7. CHs send ACK, and two clusters are formed and so on.

**Merging cluster step**
(For each cluster)
1. The CHs counts the number of CMs and if the number of CMs is < Splitting threshold,
2. Broadcast a “merging cluster signal” packet.
3. The CH that broadcasted the merging cluster signal packet and all the CMs initially connected to it, become nodes with an undecided state.
4. All nodes with an undecided state decide on their own CH by transmitting request to join signal packet to the closest CH.

**Backup CHs selection step**
(For each CH)
1. The CH request the CMs for their energy levels
2. The CH decides the backup CH. That is, the CM having maximum residual energy of the cluster.
3. The CH transmits a “backup CH-signal” packet to the backup CH to put it to sleep.

**CMs transmission step**
(Each CM)
1. Sense environment.
2. Make a data packet.
3. Transmit a data packet to a CH.

CH transmission step
(Each CH)
1. Aggregate received data packets from own CMs
2. Transmit a data packet to the BS.

Backup Mechanism
(For each CH)
1. The CH transmits “CH-failure-signal” to the backup CH to activate and handover to it when its energy level reaches a threshold.
2. The backup CH becomes the new CH which then broadcast a CH-signal to the entire sensor field
3. Nodes receive CH-signal from their backup CH and send request to join signal packet to the new CH
4. CHs send ACKs
5. The new CH selects its own backup CH and put it to sleep by transmitting a backup CH-signal to it.
6. CMs save information about the backup CH
(For each cluster)
7. If a CH is dead; breakdown or is suddenly discharged of its energy, the CM that detects a failure of its CH broadcasts a “CH-failure-signal” to the backup CH
8. Step 2 is repeated. That is, the backup CH is activated and assumes the responsibility of the CH by first broadcasting the CH-signal packet to the entire sensor field.

3.1 CH HANDOVER THRESHOLD
Simulations were conducted to determine the most energy efficient CH handover threshold by allowing a CH to use some percentage of its energy level before handing over to the backup CH. The threshold, at which the network lifetime was increased the most, was chosen and used throughout the work. The desired CH Handover Threshold ($E_r$) was set using equation (5). Every new CH selects its own threshold value.

$$E_r = E_c \times S_t$$  \hspace{1cm} (5)

Where: $E_c$ is the current energy of the node and $S_t$ is the selected threshold of 10% to 80%.

4 RESULTS AND DISCUSSION
Simulations were carried out for different CH handover threshold. Results of network lifetime and residual energies of sensor nodes were obtained and used to validate the performance of the modified model with the work of Lee and Lee (2013).

4.1 COMPARISON OF VARIOUS CH HANDOVER THRESHOLDS
Simulations for CH handover threshold of 10%, 20%, 30%, 40%, 50%, 60%, 70%, and 80% were carried out. From Figure 2, the highest increase in network lifetime was recorded when a CH handover threshold of 40% was used. Also, from Figure 3, the average residual energy until the 30th node is drained of its energy was smaller when the CH handover threshold of 40% was used. This indicates that load is more evenly distributed in the network when a CH handover threshold of 40% is used. Hence, a CH handover threshold of 40% was used throughout the simulations.

4.2 NETWORK LIFETIME AND RESIDUAL ENERGY RATIOS
The number of periods it took for 30 nodes to be completely discharged of their energy was taken as the lifetime of the network. Figure 4 shows that the network lifetime of the Modified model (mEECSM) is 11.4362% (when the 1st sensor node is discharged) longer and 7.4532% (when the 30th sensor node is discharged) longer than the lifetime of EECSM, respectively. This is due to the backup CH coupled with the CH handover threshold that aid in prolonging the network lifetime.

Also, it can be seen from the graph that the network lifetime increased faster at the beginning of the plot than towards the end of the plot. This is because it gets to a point where the Residual Energy (RE) of some nodes in the network becomes too low that they are unable to complete their tasks before their energy level becomes zero. At this point (after the discharge of 15 nodes approximately), the nodes die faster and almost simultaneously. Hence, there is no visible increase in the network lifetime due to the uniform energy depletion of nodes in both networks. The network is assumed to fail when 30 nodes are discharged of energy as stated in section 2.5.

From Figure 5, the difference between the residual energy ratios of mEECSM for the discharged of the 1st and the 30th node is smaller compared to EECSM. This shows that the sensor nodes of mEECSM consume energy more uniformly than those of EECSM with about 50.7351% on the average. Hence, the increase in the network lifetime.

![Fig. 2: Average Network Lifetime for Different CH Handover Threshold](image-url)
neighboring nodes by using modulation techniques such as the Time Division Multiple Access (TDMA) technique on the Cluster Member (CM) nodes to increase Network Lifetime.

REFERENCES
Akyıldız, I. F., Su, W., Sankarasubramaniam, Y., & Cayirci, E. (2002). Wireless Sensor Networks: A Survey Computer Networks, 38(4), 393-422.
Ali, S., Qaisar, S. B., Saeed, H., Khan, M. F., Naem, M., & Anpalagan, A. (2015). Network challenges for cyber physical systems with tiny wireless devices: a case study on reliable pipeline condition monitoring. Sensors, 15(4), 7172-7205.
Castagnetti, A., Pegatoquet, A., Le, T. N., & Auguin, M. (2014). A joint duty-cycle and transmission power management for energy harvesting WSN. Ieee Transactions On Industrial Informatics, 10(2), 928-936.
Hammoudé, M., & Newman, R. (2013). Adaptive routing in wireless sensor networks: QoS optimisation for enhanced application performance. Information Fusion, 22, 3-15. doi: http://dx.doi.org/10.1016/j.inffus.2013.02.005
Jabbar, S., Ahmad, M., Malik, K. R., Khalid, S., Chaudhry, J., & Aldabbas, O. (2018). Designing an Energy-Aware Mechanism for Lifetime Improvement of Wireless Sensor Networks: a Comprehensive Study. Mobile Networks and Applications, 1-14.
Kamaybour, N., & Hoang, D. B. (2011). Modeling overall energy consumption in Wireless Sensor Networks. arXiv preprint arXiv:1112.5800, 1-8.
Lee, K., & Lee, H. (2013). Energy-efficient self-organized clustering with splitting and merging for wireless sensor networks. International Journal of Distributed Sensor Networks, 9(3), 1-12. doi: 10.1155
Liao, Q., & Zhu, H. (2013). An energy balanced clustering algorithm based on LEACH protocol. Paper presented at the International Conference on Applied Mechanics and Materials. 1138-1143
Liu, D., & Ning, P. (2007). Security for wireless sensor networks (S. Jajodia Ed. Vol. 28). 233, Spring Street, New York, NY 10013, USA: Springer Science & Business Media, 1 & 2.
Oreku, G. S., & Pazynyuk, T. (2016). Security in wireless sensor networks. Switzerland: Springer International Publishing. pp 41-51.
Ou, Y., Tian, Y., & Liu, M. (2017). A distributed self-organizing clustering routing protocol for wireless sensor networks. Paper presented at the Chinese Automation Congress (CAC), 2017. 3791-3795
Patel, M., Chandrasekaran, R., & Venkatesan, S. (2004). Efficient Minimum-Cost Bandwidth-Constrained Routing in Wireless Sensor Networks. Paper presented at the International Conference on Wireless Networks. 447-453
Pietrabissa, A., Liberati, F., & Oddi, G. (2016). A distributed algorithm for Ad-hoc network partitioning based on Voronoi Tessellation. Ad Hoc Networks, 46, 37-47.
Pitke, K., Kumar, P., & Singh, S. K. (2017). A Load Balancing Cross Clustering Approach in Wireless Sensor Network. Paper presented at the Proceedings of the 7th International Conference on Computer and Communication Technology. 52-57
Talikoti, A., & Jayashree, A. (2012). Bandwidth and Energy Management in Wireless Sensor Networks. International Journal of Advanced Research in Computer Engineering & Technology, 1(8), 41-45.
Torkestani, J. A. (2015). An Energy-Efficient Topology Control

5 CONCLUSION
A modified EECSM for wireless sensor networks using CH handover mechanism was developed and implemented. The modified model has integrated a backup CH technique and a suitable CH handover threshold. The model attempts to maintain a fair balance in energy consumption of sensor nodes with the consequence that it prolongs network lifetime. This was achieved by allowing the backup-CH to take over the responsibilities of the CH when the CH handover threshold is reached or when a breakdown of the CH occurs. This approach helped to reduce the frequent exchange of control signal packets in the network. Simulations were carried out using MATLAB R2013a to illustrate its performance. From the results, the Modified EECSM was able to improve Network Lifetime and Residual Energy Ratio by 7.4532% and 50.7351% over the Unmodified EECSM respectively. The work can be extended to consider mitigating interference among
Mechanism for Wireless Sensor Networks Based on Transmit Power Adjustment. Wireless Personal Communications, 82(4), 2537-2556.

Vijayan, K., & Raaza, A. (2016). A novel cluster arrangement energy efficient routing protocol for wireless sensor networks. Indian Journal of Science and Technology, 9(2), 1-9.

Wajgi, D., & Thakur, N. V. (2012). Load balancing based approach to improve lifetime of wireless sensor network. International Journal of Wireless & Mobile Networks, 4(4), 155.

Zayene, M., Habachi, O., Meghdadi, V., Ezzeddine, T., & Cances, J.-P. (2017). Joint delay and energy minimization for Wireless Sensor Networks using instantly decodable network coding. Paper presented at the International Conference on Internet of Things, Embedded Systems and Communications (INTEC), 2017. 21-25

Zeb, A., Islam, A. M., Baharun, S., Mansoor, N., & Katayama, Y. (2015). A Survey on Self-Organized Cluster-Based Wireless Sensor Network. Jurnal Teknologi, 76(1), 3-11.