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Improved Data Aggregation Clustering (IDAC) in an Energy Efficiency Perspective

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Abstract- WSNs use autonomous sensors spread across an area of interest to detect various occurrences. These sensor networks needed extensive planning, building, and deployment to meet real-time sensing and monitoring needs. These nodes have microprocessors, transceivers, power, memory, and wireless modules. Sensors organize, combine, send, receive, and process massive amounts of data. This means they must efficiently use memory, CPU power, and, most critically, energy to enhance longevity and productivity. . Clustering helps wireless sensor networks last longer (WSNs). It needs clustering sensor nodes and selecting "cluster heads" (CHs) for each cluster. This paper presents an improved clustering algorithm Improved Data Aggregation Clustering (IDAC) that will minimize energy and improve network lifetime..

Keywords- Clustering, Data aggregation, Energy and WSN.

I. INTRODUCTION

A wireless sensor network is a collection of sensor nodes that detect physical events in a particular region. Animal tracking, weather control, medicinal applications, military management, and infrastructure maintenance are among the expanding WSN applications. Each sensor within a WSN has a limited quantity of battery power. Power demands that the sensor sense, transmit, receive, and process information.

Each step requires a certain amount of energy, lowering the capacity of the battery. Wireless sensor networks require an energy source with limited capacity. Different WSN nodes keep track of values, which are periodically relayed to the base station via node communication and cluster heads. The cluster heads' sensing nodes transmit data to the base station. The WSN battery is used to monitor the energy level of the sensor node. [3]

It is difficult to replace the battery more than once in remote locations when sensors are dropped from small aircraft. When there are inadequate nodes in a network as a result of excessive energy use, the routing procedure is typically complicated.

The transmission of data from sensor nodes generates a considerable amount of network traffic. Yet, this congestion can be avoided by adopting effective and efficient detection techniques. Due to the limited source space, effective source power management is essential for increasing the network's life span. In order to increase the network's lifespan, resource utilization should be maximized. [5]

The WSN has multiple modes of operation, including communication and sleep evaluation. The quantity of energy consumed by the nodes during communication is directly proportional to the network's ability to traverse greater distances. To increase the longevity of a WSN, greater attention must be placed on communication nodes.

II. CLUSTERING IN WSN

Due to the fact that WSN applications serve a vast array of disciplines and domains, WSN administration must be conducted at the most fundamental level. Clustering appears to be an effective method for managing and extending the lifespan of sensor nodes. According to [5,] cluster development should be given a great deal of attention. The sensor nodes are clustered dynamically, and the established cluster is periodically remodeled. At the beginning of each cycle, the originator will be selected, and messages will be spread throughout the cluster through a variety of approaches previously outlined in relation to cluster organization. In order to conserve energy, a method of broadcasting based on several hops is employed. After the formation of clusters, the selection of heads to serve as cluster leaders is the subsequent step. The cluster heads are responsible for gathering data from their members and transmitting it to the base station. [8]

When analyzing a hierarchical network to handle the issue of energy consumption in WSNs, cluster size is always a crucial component to consider. When a cluster is small, intracluster communication does not necessitate a significant increase in energy, but it does compromise the network backbone design [9]. When the cluster size is kept small, the network faces minimal stress; nonetheless, intra-cluster connections significantly increase the network's power consumption and diminish its lifetime. These factors necessitate a trade-off throughout the cluster formation procedure. The location of the node inside a cluster, the size of the cluster, and its closeness to the base station are a few of the variables that may influence the utilization of the energy resource.

Many algorithms to improve energy efficiency have been developed and studied in recent years. This section describes some algorithms that conserve energy. [11] LEACH is the most effective technique for conserving energy in WSN, a topology with a single hop in which the cluster head is chosen at random. Weak and randomly dispersed group heads were used to form the network cluster heads. Although this method has been adopted for use in numerous WSN applications, it has not been optimized in terms of energy consumption. LEACH-C is [13] more sophisticated than LEACH, utilizing the same metrics with the exception of cluster formation. The cluster was constructed using the nodes' remaining energy. [12]

HEED is an effective, energy-efficient technique that takes neighboring nodes into account during cluster head distribution and randomly selects the cluster head, which changes during iteration. [17] The EECS (Energy Efficient Clustering Scheme) is attractive due to its balanced clustering in the selection of cluster heads and its use of several criteria to promote energy efficiency. FLOC (Fast Local Clustering) builds clusters of comparable size with non-overlapping nodes. [19] DWEHC (Distributed Weight-Based Protocol for Energy-Efficient Hierarchical Clustering) creates balanced clusters with no overlaps, which are then dispersed using the Weight dependent Protocol for Energy Efficient Hierarchical Clusters. These two algorithms appear to be the most efficient in energy conservation in WSN. The LEACH algorithm combined with the Weighted Spanning Tree concept is said to perform better than LEACH.

By generating spanning trees, the GSTEB algorithm displays efficient routing, resulting in an increase in network lifetime. [21] GEAR (Geographic and Energy Conscious Routing) claims to improve energy efficiency by considering multiple criteria, including source and destination location, network density for interrupted communication, and energy prices. [22]

PEDAP (Power Efficient Data Collecting and Aggregation Protocol) is a two-algorithm architecture that utilizes optimal spanning trees to achieve its primary objective of power efficiency. [14] PEGASIS (Power-Efficient Selection in Sensor Information Systems) is a chain-based protocol optimized for enhancing sensor information systems. According to a study, collecting data from sensor nodes based on fixed settings improves energy efficiency by 50 percent, but introduces data overhead. [23] COSEN (Chain Driven Sensor Network) is a chain-based algorithm that focuses on data collection with minimal energy use. [6]

While examining protocols that can promote low energy consumption, reduce transmission costs, and balance the load, we must categorize the protocols based on our requirements. This section will examine many cluster-based routing methods with low energy usage. [15] The Borderline Responsive Energy Efficient Network (TEEN) is a protocol that conserves energy and promotes network lifetime. It is not possible to quickly aggregate data using this protocol due to the absence of connection between sensor nodes and cluster heads. [16]

Periodic Adaptive Limit the Responsive Energy Efficient Network Protocol (APTEEN) is an enhanced version of TEEN that can collect and transmit data between sensor nodes, but only with the support of a few secured transmission protocols. [14] Power Efficient Gathering in Sensor Information Systems (PEGASIS) is a hierarchical system that transfers packets to the base station sequentially using a greedy algorithm. The nodes create a chain to transmit data, and if any node in the chain fails, the chain must be reconstructed. Each sensor node in the deployment region serves as a communication hub for transmitting data to the base station.

The majority of WSNs utilize the TDMA-based MAC protocol, which is an energy-conscious technology (LEACH). The fundamental objective of this protocol is to reduce base station energy usage and establish data transport clusters. After each round, sensor nodes are generated using the stochastic process and the CH's purpose is to aggregate, compress, and transport data. It transfers data from the cluster to the base station by calculating resident data.

This protocol is optimal on uniform networks but not diverse ones. [24] Stable Election Protocol (SEP) is a clustered heterogeneous protocol based on each node's weighted probability that the remaining energy will become CH. It operates on two distinct sorts of nodes: standard and advanced. Advanced nodes use more energy for data transmission and aggregation than standard nodes. [12] To extend network life, the Hybrid Energy Efficient Distributed (HEED) protocol is utilized. The first is residual capacity, and the second is node density, both of which are utilized to determine which CHs to employ. [25] The DEAR protocol produces routing paths from the residual energy of a network node. Consideration is given to delivery time, energy consumption, and data reliability. [13]

LEACH-C is a cluster-based mechanism that picks base station CHs. At the beginning of each round, the amount of energy in the nodes is relayed to the base station. The bases select the CHs in accordance with the measurements supplied by the nodes. The base station selects the CHs based on the node-sent metrics. This approach does not generate better results than the LEACH method when the sensor nodes are close to the base station. This protocol's primary drawback is that the CHs are not distributed.

[26] The protocol for deterministic energy-efficient clustering (DEC) proposes a superior alternative for CHs. One hop or more hops may be required to complete communication. Single-hop data packets are only transmitted to a single neighbor, but multi-hop data packets are sent to numerous neighbors simultaneously, costing more resources. [7] Dual Cluster Head Routing Protocol (DCHRP) aims to maximize network life time by utilizing three levels of heterogeneity in selecting CHs. This protocol's ultimate objective is to restrict CH selection to reduce energy consumption, as greater energy is required during CH selection.

This approach minimizes the number of clusters and achieves three levels of heterogeneity in three stages: CH selection, cluster creation, and base station communication. Due to the fact that transmission costs are typically larger than calculation costs, it is necessary to cluster sensors. When the cluster idea is applied, the duty for data processing is allocated to one of the clusters to avoid data transmission over long distances. As data is transported across short distances, energy consumption is decreased. Many clustering techniques are based on this concept, and we will examine some of them in this section. [28]

EHMR is a hierarchical technique that combines inherent clustering and uncast load balancing for multipath pathways. It utilizes numerous paths with an on-demand load balancing function that transfers the full load to another path in the event of a path failure. In this method, sensor nodes are randomly distributed and allocated to a certain transmission range. This approach utilizes seven interconnected algorithms to perform load balancing with little energy use. The first method is Neighbor Discovery, which is designed to classify neighboring sensors and update their hop count to the base station.

The second process is the Hop Number Update procedure, which involves the base station retransmitting the HU packet to the nodes after altering the hop number. The third method is the Path Request algorithm, which recognizes the various paths to commence transmission between neighbors. The Highest Energy and Minimal Hop algorithm will determine the primary route with the highest residual energy and shortest distance to the hop. The sixth algorithm, Path Request Reception, collects the set of all neighbors and launches the request for distinct paths.

The Destination Reply Reception procedure will supply the packet ID and path information from which the packet was delivered to the source node that launched the transmission. The alternate path will be decided by the final high energy and minimum hop algorithm in the case of a track failure. Typically, the route repair is performed locally to prevent interfering with the existing transmission and to shift the load to the repaired route once the way has been restored. EHMR has proven to be energy efficient, balanced, and successful in terms of load. EHMR is more effective as network density grows.

There is a mechanism in multi-hop networks that use static links. In multihop networks, sensor nodes communicate data to the base station using a static connect method. There is a possibility that the data packets will traverse the network in this scenario. An efficient clustering algorithm with numerous drains was presented to address this issue. Then, given the standard energy conservation technique utilized by the majority of wildcard sites, LEACH, a drawback is discovered: a node with minimal waste energy is frequently susceptible to failure, resulting in frequent network interruptions. A particle encoding system for data packet routing and a clustering algorithm are developed to remedy this problem. [29]

The Clustering Limited Member Node (LmC) technique decreases the number of cluster member nodes below a predetermined threshold. This algorithm determines the cluster head based on residual signal strength, energy expenditure, and distance from the base station. The efficiency of the clusters is influenced by the spreading range of the base station.

This technique has demonstrated rapid packet delivery while extending network life. In a WSN, traditional load balancing techniques such as Breadth First Search and Dijkstra's algorithm, which seeks the shortest path to route data packets, can be utilized. Load balancing fundamental purpose is to eliminate hot spots in order to maximize the network's survivability. [33]

To equalize the load, a heuristic algorithm that focuses on the transfer power along the data transmission channel was designed so that each network node receives the same transmission power. The non-linear programming approach is updated based on the WSN architecture and traffic distribution in order to extend the network's lifetime. A research study presents a control principle to reduce link use by instituting a network controller to monitor transmission. [31] Energy Gauge Node (EGN) is a method for minimizing energy usage by utilizing sensor nodes effectively and resolving load balancing concerns. EGN nodes are utilized in WSNs consisting of conventional nodes because they have a large battery, a powerful processor, a rapid communication speed, and a huge amount of storage.

The network's EGN nodes are responsible for processing the nodes' waste energy and transmitting information regarding the Hop collection. Two sorts of packets are employed for this purpose: route requests initiated by EGN nodes and route-respond packets recognized by conventional nodes. EGN nodes employ the node ID, signal energy, and round-trip time supplied in the route response packets to calculate the residual energy of the nodes. Initially, every normal node in the network allocates maximal energy and is deemed efficient; but, after transmission time, the energy of the nodes depletes and they fall into the regular or critical group [34].

The EGN nodes' residual energy calculations are used to monitor the sleep cycle. Prior to the complete number of node failures, the functioning of the active nodes is optimal. Under this strategy, the network remains operational for a longer period of time. [35] Energy-balanced Joint Routing and Asynchronous Duty Cycles are recommended for load balancing that adds to network longevity optimization. In order to govern the transfer power of the sensors in an energy-balanced model, three algorithms are incorporated into a network to work in tandem to balance energy consumption over a given time period. Sending hello back packets on a frequent basis ensures the network's access. WSN data collection refers to the device that transmits data obtained by sensor nodes to cluster heads and base stations.

This section highlights novel data collection techniques for energy use. [37] In today's deployment research, mobile sinks are a prevalent strategy for ensuring consistent energy usage between nodes. The vast majority of WSN applications have adopted the concept of mobile sinks, which promises to improve network efficiency. [38] There are three mobility models for mobile sinks, according to the most recent research: random path sink mobility, fixed path sink mobility, and control path sink mobility.

The mobile sink(s) that move randomly throughout the deployment area are referred to as having random track sink mobility, whereas mobile sink(s) with a predetermined track have fixed track sink mobility. If the route of a mobile sink can be monitored, the device is known as a mobility route controller. The data from the sensor nodes is transmitted to the cluster heads, who subsequently deliver it to the sinks via single hop or multihop communication. Many study methodologies that can contribute to energy conservation are discussed. [39] Lowest Possible Energy Consumption Maximum Data Gathering (MDGMEC) is a strategy that uses the fixed path mobility paradigm to collect data from sensor nodes.

Shortest Path Trees (SPT) is a data collection technique; however it has the disadvantage of causing an imbalance in network traffic. In this instance, the mobile sinks are intended to travel at a constant speed; however the speed and duration are insufficient for the cluster heads to communicate their data in full. To address this requirement, the data will be distributed uniformly among the cluster heads; however, this does not ensure optimal performance. By employing the random mobility model, it is a huge disadvantage to know the patterns the mobile sink follows, but it is possible to collect data in a timely manner when using pre-determined routes. Then, a path(s) must be developed in order to increase the network's output and address the energy whole issue.

The queuing technique is likewise recommended for efficient data collecting, but its considerable delay for aggregation makes it unsuitable for large-scale WSNs. In a variety of instances, it may be suggested that a large number of sinks be utilized to improve energy efficiency, but that implementation costs be minimized. Fog is a multi-mobile sink technology that aims to improve performance while reducing transmission latency. [42]

The Reduced k-Means (RkM) and [43] the Delay Bound Reduced k-Means (DBRkM) algorithms and MS scheduling approaches are utilized for route discovery. [44] Ant Colony Optimization, an effective data gathering technique, is utilized in a research investigation to identify the optimal path. This strategy eliminates unnecessary cluster centroids while focusing on energy consumption, and cluster heads are selected depending on their weights to increase transmission range. This strategy enhances network throughput and longevity.

III. THE PROPOSED CLUSTERING ALGORITHM

The base station is located outside the sensing region. All the sensors are provided with same amount of energy initially. All the sensors can sense data and send it to the base station. The base station is aware of the location of all the sensor nodes. The cluster heads can receive and send data. The probability of becoming a cluster head is denoted by p. A node which has become cluster head shall be eligible to become cluster head after 1/p rounds. The sensing region has 100 sensor nodes. The energy of each node initially is denoted Emax.

Initially the base station gathers the details of the location of the nodes. As the sensor nodes are deployed deterministically using TriCentroid algorithm, the location remains fixed throughout the lifetime of the network. The sensing region is divided into zones and a cluster head is assigned for each zone.

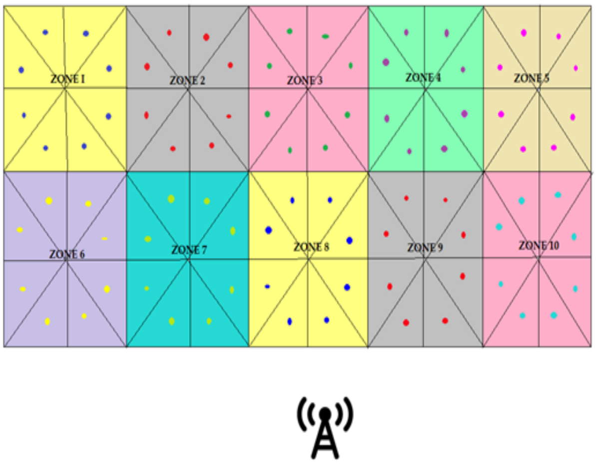

Fig 1. Node Deployment.

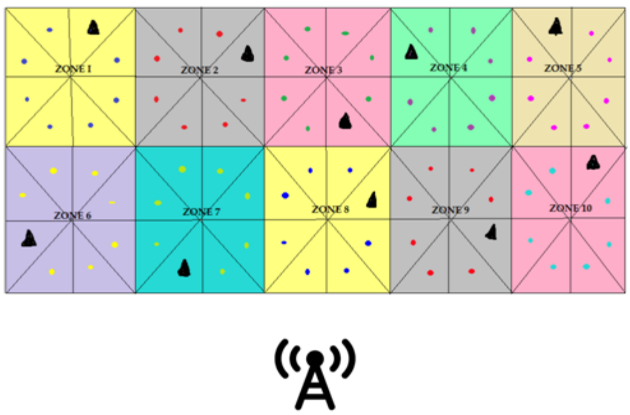

Fig 2. Cluster Head Selection.

As all the nodes in the sensing region are initially supplied with same amount of energy Emax, the cluster heads are elected with probability p where p= 1/number of nodes in a zone. Initially all the nodes in the zone have equal probability and hence the cluster head is selected randomly. Once the cluster heads are elected, they broadcast their identity to all the nodes of the network. The nodes find the closest cluster head and join them to form actual clusters.

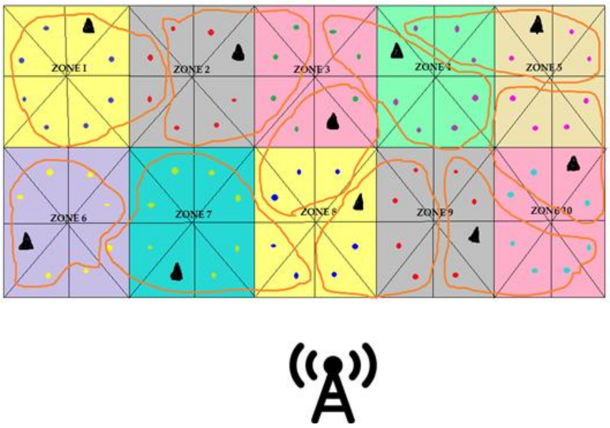

Fig 3. Cluster Formation.

The CH prepares the data sending schedule and sends it to its members within the cluster. Only 50% of the nodes in a cluster are in active mode and the remaining 50% nodes in a cluster are in sleep mode. The sleep and active modes are switched on fixed time slots. The CH receives data from each node, compresses the data and sends it to the BS. The new CH is elected based on the residual energy of the member nodes. A threshold is determined in this case. The node with the maximum residual energy becomes the next CH.

If the residual energy of all the nodes fall below the threshold, then the next CH is determined based on the criteria given below:

- A node has not become a CH for the past (1/p) – 1 rounds.
- The ratio of the current energy of the node to the initial energy of the node must be equal to one. $\frac{E_{res}}{E_{max}} = 1$
- The next CH must be nearest to the existing CH where the hop count must be 1.

Data aggregation is performed in the cluster heads and the base station. In the cluster heads data aggregation is performed in two cycles. In the first cycle the aggregation is performed at the cluster heads for the nodes that are active during the current time slot and in the second cycle aggregation is performed for the nodes that have become active in the next time slot. The data sensed by the members are sent to the CHs and the CH splits them into multiple datasets. A standard threshold value is set initially to accept and discard the data sensed. Euclidean distance is calculated among the datasets and compared with the standard threshold value.

Based on the conditions given below the datasets may be accepted and discarded. Let ds_i and ds_j be the two data sets. The standard threshold S is defined initially. The Euclidean distance between these data sets are calculated using the equations given below:

$$\boldsymbol{\varepsilon_d} = \sqrt{\sum_{1}^{t_s-1} (\boldsymbol{ds_i n} - \boldsymbol{ds_j n})^2} \leq \boldsymbol{S}$$

$$\boldsymbol{\varepsilon_d} = \sqrt{\sum_{1}^{t_s-1} (\boldsymbol{ds_i n} - \boldsymbol{ds_j n})^2} > \boldsymbol{S}$$

If ε_d is between ds_i and ds_j ≤ S, then the elements in both the sets are similar. In that case the elements in one set are retained and the other is discarded. If ε_d is between ds_i and ds_j > S, then the elements in both the sets are dissimilar. In that case the elements in both the sets are retained. This process is done by all the cluster heads. After aggregation is completed the refined data is sent to the base station. In the base station the second level of data aggregation is performed similar to the one performed in the CHs.

The data received from different CHs are split into data sets by the base station and the Euclidean distance is calculated among the data sets based the conditions given. The data is refined by this level of aggregation and duplicate data is completely removed thereby enhancing accuracy in the sensed data.

IV. PERFORMANCE ANALYSIS

The proposed method has been tested with a hundred nodes in the environment depicted in Table 1. The sensor nodes are distributed at random across a 100 m x 100 m field. The sink node is assumed to be in the centre of the field's top periphery. Each cluster will contain approximately 20% of the total nodes in this work. Network lifetime, delay, throughput and energy consumption are computed and compared with the LEACH and EHMR algorithms.

Table 1. Simulation Parameters.

Parameter	Value
Network size	100 x 100
No. of sensor nodes	100
Radio propagation range	200 m
Channel capacity	2 M bits/s
Initial energy	1 J
Data packets	3200 bits
Simulation time	180 s
ε_{fs}	10 pJ/bit/m^2
ε_{mp}	0.0013 pJ/bit/m^4

Chart 4 provides a visual representation of the amount of energy that is consumed by the LEACH [11], EHMR [28], and the proposed IDAC algorithms. The sensing environment, the calculation of data, and the transmission of data are all three factors that might have an impact on the total amount of energy that is expended.

According to Chart 4, the suggested algorithm uses up fifty percent of the available energy after nine hundred iterations, whereas LEACH [11] and EHMR [28] each use up fifty percent after three hundred and fifty iterations. Moreover, the suggested algorithm uses up fifty percent of the energy after nine hundred iterations. The amount of energy that is required to send the data is decreased, which results in an increased network lifetime. Because the data transmission in the proposed method is determined by both the amount of residual energy and the distance to the sink, the amount of energy that is required to send the data is decreased, as well.

This demonstrates that energy is balanced throughout the network, as can be seen in Chart 4. This not only serves to effectively balance the load on the network, but it also leads to an increase in the lifetime of the network. Charts 2 and 3 illustrate the possible latency and throughput values that can be achieved by the proposed IDAC as the number of network rounds increases. These values are shown to be proportional to one another. When compared to the LEACH and EHMR schemes, it has been established that the planned IDAC is 12% and 17% faster than those schemes, respectively. It was found that the IDAC technique presented by the authors significantly enhanced throughput when compared to the LEACH and EHMR methods by a startling margin of 13% and 15% respectively.

This was established after comparing the IDAC methodology to both of these approaches. The ability of the proposed IDAC solution to enforce performance is the primary factor that provides support for the claim that it can significantly reduce latency while also significantly improving throughput. This claim is substantiated by the fact that the solution is capable of enforcing performance.

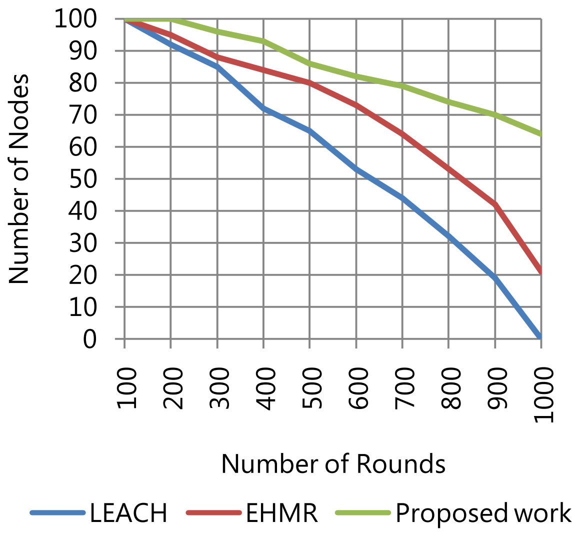

Fig 1. Chart 1: Network lifetime.

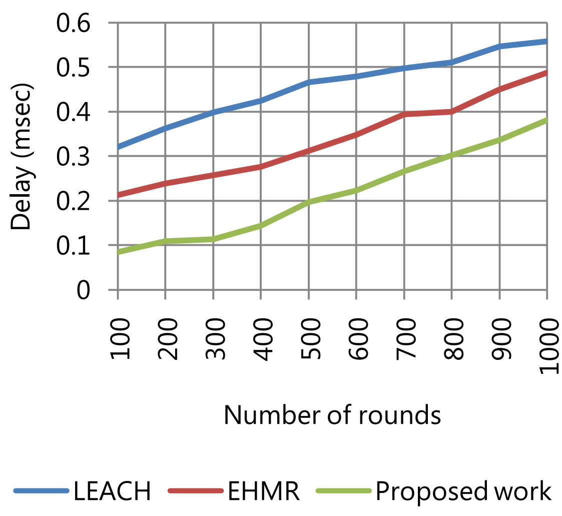

Fig 2. Chart 1: Delay.

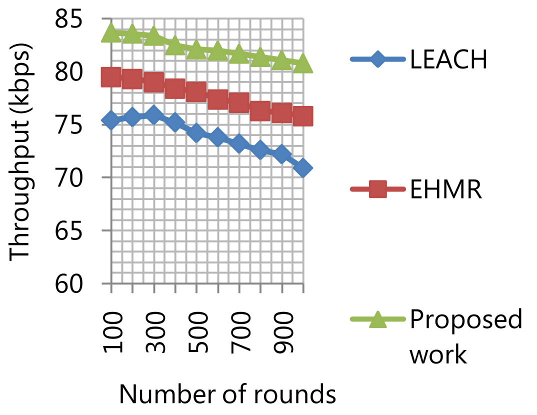

Fig 3. Chart 1: Throughput.

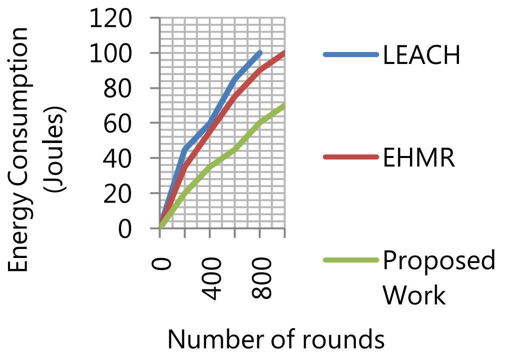

Fig 4. Chart 3: Energy Consumption.

V. CONCLUSION

This research presents a novel energy-efficient clustering method that has the potential to lengthen the lifetime of networks and improve their throughput, all while lowering their overall energy requirements and lag times. This approach is very effective at building balanced clusters, which helps to balance the load on the network.

The rotation of cluster heads leads to a reduction in the number of nodes that die, which ultimately results in a more stable network. In the not-too-distant future, energy-efficient transmission might be accomplished by the implementation of various energy-efficient routing approaches.

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