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Energy-Efficient Multi-Factor Based Clustering Approach for Energy Harvesting Wireless Body Sensor Networks

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Abstract-The medical industry, sports, entertainment, and social welfare are just a few of the many fields that can benefit from Wireless Body Area Networks (WBANs). WBANs rely heavily on Base Station Nodes (BSNs), also known as Sensor Nodes (SNs). Smaller sensor nodes are typically quite resource constrained. As a result, efficient energy use is crucial during the planning stages of WBAN designs. The radio frequencies of the sensor nodes are extremely vulnerable to noise and interference and they have limited capacity for storing energy, processing data, and archiving observations. As a result, they pose a risk to the network's efficiency, longevity, and throughput. Energy harvesting techniques used in the Internet of Things that rely on wireless sensor networks are one solution to the problem of excessive power usage. While most research on energy harvesting wireless-sensor-networks has focused on also Energy-Efficiency (EE) or Quality-Of-Service (QoS), a few recent studies have tackled the issues of clustering and routing in these systems. An effective method is required, one that makes economical use of energy while also guaranteeing high service standards. This study proposes an intelligent protocol, the Energy-Efficient Multi-Factor-Based-Clustering-Approach (2EMFCA), that takes into account both the efficiency of energy use and the dependability of communications. It uses a weighted-function specified by many factors such link statistics, neighborhood-density, residual-energy, and the pace of energy harvesting of nodes to determine a trustworthy cluster head to lead the network. When selecting a cluster's head, taking into account such criteria helps nodes conserve energy by routing data across links with a lower probability of packet loss due to signal-to-noise ratio. Improvements in network throughput, energy efficiency, and lifetime, as well as increased service availability, are all possible thanks to a reduced packet loss ratio in IoT use cases. Our suggested method beats the current low-energy efficient clustering-hierarchy and other modern protocols in terms of Network-lifetime (NL), Residual-Energy (RE), and Network-Throughput (NT), as shown in a series of investigations utilizing Network-Simulator-2(NS2).
Key Terms - Clustering, Harvesting, Network-stability, sensor nodes, link statistics, WBA.

1. Introduction

A new type of network known as WBANs has arisen as one of the active study topics because of developments in communication technology and electronics. Its low price, versatility, and capacity for remote monitoring have contributed to its rising popularity. It suggests fostering services across domains, such as mobile healthcare, defense, industrial, academic, and commercial ones [1]. Wireless sensor nodes, also known as "wireless sensors," are the building blocks of WBANs. These nodes are intelligent, compact, cheap, low-powered, and lightweight portable computer radio devices that can be worn or implanted. These Sensor Nodes (SNs) are used in close-proximity to a human-body, can sense/observe physiological and nonphysiologically data, and then send this information via wireless connection to a sink-node [2]. These sensor nodes have a low power supply because of their small size. Since these sensor nodes are often implanted inside a human, they cannot be removed for charging or replacement. Battery-powered nodes have a limited lifespan, which not only hinders performance but also reduces service availability. To lessen the impact of power shortages, researchers have been working to perfect energy-saving methods, topological designs, and conservation strategies [3]. Although WBANs have several advantages, limited energy remains a major obstacle. High path-loss and limited communication range are two more major concerns with WBANs. In addition, the Energy-Efficiency (EE) of traditional routing protocols is worse, despite the fact that they often offer an end-to-end communication solution. The excessive power requirements of these routing protocols make them inappropriate for use in WBANs. Hop-to-hop (multi-hop) communication, a routing protocol tailored to WBANs, is advocated as a solution because of its low energy usage [4].

Energy Harvesting (EH) is another viable technique to solving the energy shortage problem. Harvesting energy from various environmental sources, for instance body-temperature, motion, vibration, ambient-light, etc., is accomplished via a Sensor Node (SN) that is proficient of doing so, as shown in Figure 1. By maintaining a steady flow of power to WBANs' wireless sensor nodes, Energy Harvest (EH) extends their useful lifespan [5]. Routing protocols and Energy Harvest (EH) approaches, in particular, need further improvement to become more optimal and energy efficient before communication protocols can be widely implemented. As a result, a protocol that takes Energy Harvest (EH) into account is necessary if WBANs are to function at their best [6].

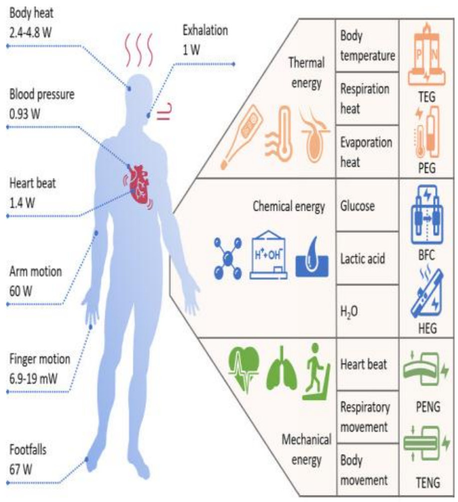

Figure 1 Energy Harvesting Apparatus in Human Environment

The restricted battery-driven power supply of Sensor Nodes (SNs) in IoT systems is a major concern, since it limits the amount of time such network tools can offer services and has a negative impact on their performance. In WSNs, the node's power is used for sensing activities, giving signals, computing, and transmitting data [7]. The latter has a better efficiency as an IoT node in terms of energy consumption. Therefore, it is crucial that sensing devices optimize data transmissions to make the most of the available energy. As a result, many studies have targeted the development of WSN routing protocols that effectively utilize energy. Energy efficiency in data communication processes is an important goal, and many protocols have been proposed to achieve this goal. In both WSNs and IoTs, there is still room for improvement when it comes to energy efficiency. As a result, the sensor nodes' communications become less reliable [8].

Numerous routing protocols for WSN, covering a wide range of categories, have been devised to work around this energy constraint. Plane routing, location-based routing, and hierarchical routing are all types of routing systems. In particular, hierarchical routing protocols are preferred because of their lower power consumption [9]. In these protocols, the network is partitioned into many logical sections, each of which is known as a cluster. One node (the Cluster Head CH) is selected from among the cluster's many nodes, and the other nodes (the cluster members) function normally. Each Cluster Head (CH) gathers data from its associated nodes, aggregates it as needed, and transmits it either directly or via another Cluster Head (CH) to the Base Station (BS). Nodes in the Cluster Head (CH) consume more power because they have more responsibilities, such as collecting packets from members, aggregating them, and sending them on to the Base Station (BS) [10]. Consequently, a node playing the Cluster Head (CH) for an extended period of time runs the risk of rapidly running out of energy. Therefore, the Cluster Head (CH) is not static and is instead passed around to different nodes after a set amount of time (a ''round'') in order to ensure optimal energy consumption. Each time around, a new Cluster Head (CH) is chosen by the selection algorithm in accordance with the protocol's established guidelines. Choosing a reliable Cluster Head (CH) is crucial for improving energy efficiency and throughput, which in turn extends the lifespan of the network [11].

To address the issue of energy scarcity in WSNs, hierarchical routing methods partition the network into subnetworks. The data transmission between the member nodes (source) and the Base Station (BS) (destination) in a cluster relies heavily on the Cluster Head (CH) node, which must be both dependable and efficient. Since the year 2000, many different clustering techniques have been suggested for this task [12]. Some of the criteria used to determine which Cluster Head (CH) to connect to include the current energy level of the node, the standard distance amid the Cluster Head (CH) and its members, the number of nearby nodes, the network's proximity to the Base Station (BS), and the rate at which energy may be harvested from the network's environment. While taking these into account helps extend the life of a network, other factors, such as path-losses and weaker-links amid Sensor Nodes (SNs), which lead to retransmissions of packets, have a much more significant impact on the performance and energy consumption of Sensor Nodes (SNs) [13]. The network lifetime &throughput of the network are negatively impacted by packet retransmissions because they force the broadcasting nodes to use added energy and cause more end-to-end delay. In addition, because WSNs function in hostile settings, where noise in the neighborhood is common, the excellence of linkages amid nodes deteriorates and path-losses occur frequently. Since better link quality can increase the network's lifetime and throughput, it is a crucial factor in ensuring the network's reliability and efficiency [14].

In light of the foregoing, a clustering mechanism is needed to guarantee the optimal utilization and preservation of the node's energy, increased throughput, and reduced end-to-end delay. Hence, this research suggests a competent and trustworthy Cluster Head (CH) - selection system for WSNs that are conscious of energy harvesting. Assigning the Cluster Head (CH) role to the most appropriate nodes in each cluster is where the proposed approach focuses its attention [15]. The scheme's selection criteria guarantee maximum throughput while minimizing retransmissions, route losses, and energy consumption at each node. The present energy state of the node, the rate at which energy is harvested, the density of its neighbors, and the link quality (as measured by noise in links) all play a role in the decision of which Cluster Head (CH) to use. The first three factors control how efficiently energy is used, while the fourth assists to limit the collection of nodes that display re-broadcasting and delay because of weaker linkages with the neighboring nodes. Noise in the area is a major contributor to deteriorating connections. For this purpose, the Signal-to-Noise Ratio (SNR) of wireless connections is taken into account by nodes together with other criteria while choosing a Cluster Head (CH). In this way, a good Cluster Head (CH) is chosen that saves power by decreasing the number of times packets need to be resent, reduces latency and maximizes throughput from beginning to finish. Together, these features lengthen the lifespan of a network and guarantee the safe arrival of data packets. Network Simulator 2 (NS2) simulation tests were used to evaluate the proposed method, Energy-Efficient Multi-Factor-Based-Clustering-Approach (2EMFCA). Our findings demonstrate that Energy-Efficient Multi-Factor-Based-Clustering-Approach

(2EMFCA) provides significant improvements over traditional methods in terms of energy efficiency, network robustness, throughput, and lifetime.

The following is a list of this work's most significant contributions:

• To boost the functionality of wireless body-area networks, an Energy-Efficient Multi-Factor-Based-Clustering-Approach (2EMFCA) protocol is proposed.

• When compared to other protocols, this one has a better packet delivery ratio &security, less time spent detecting attacks, less power usage, and less delay.

• This protocol can also be implemented in other types of wireless body-area networks, including those used in healthcare and environmental monitoring.

This study is structured as follows: Section 2 discusses certain cutting-edge routing methods and concludes with a comprehensive overview. Performance and evaluation of the suggested protocol, as well as the WBAN system model, are examined in section4. The final section of the report summarizes the findings and examines what comes next.

2. Related Works

Among the many obstacles that WSNs must overcome is the need for faster, more reliable communication and shorter transmission delays. Sensor node energy consumption is related to these needs in some way. WSNs typically run in mission-critical applications, such as those that deal with sensitive information in real time; as a result, they need to be able to communicate with Base Station (BS) with less delay, more efficiency, and lower energy consumption. Many clustering strategies, both for conventional and energy-harvesting-enabled WSNs, have been presented in the literature to accomplish these aims. In this section, we will go over some current and state-of-the-art research.

Throughput and latency are the determinants in a Quality of Service routing protocol. The delay-tolerant protocol guarantees on-time packet-delivery, while the reliability-based protocol maximizes throughput with minimal delays. When choosing the forwarding node, took link eminence into account. In this strategy [16], the connection with the utmost weight among its neighbors is selected. Yet, the primary shortcoming of the study is that it dnt evaluate weights based on the nodes' energy levels. Delay was identified as the primary QoS metric [17]. In this approach, we derive cost function using link reliability, RE, and queue length. With only a single sink taken into account, however, losses are considerable and energy consumption drops precipitously as iterations increase. While network eminence &energy are not taken into account in the computation, did consider important data routing as the key QoS criterion. A protocol with guaranteed data streaming was proposed.

The battery life of a WBAN is short because to its tiny size and portability. Some energy is used up in WABN, depending on the circuitry, the amount of bits being transmitted, and the distance. They [18] outline the numerous mechanisms proposed by the various energy-aware routing algorithms that have been developed to reduce battery use and increase the lifespan of networks. In order to create a maximum benefit function, accounted for factors. The energy drains more quickly, though, because there is just one sink node [19]. Fuzzy logic was employed for the optimization of a cost-function proposed that takes residual energy and link quality into account. Due to the protocol's ban on direct broadcast to a sink-node, energy is quickly depleted. When developing the cost-function, took a number of factors into account. Two sinks and node clustering form the basis of this protocol. Since sending data directly to the sink is prohibited, there will be considerable latency [20]. This study also prioritizes minimizing delays while optimizing throughput at the expense of energy consumption at the nodes. Humans are vulnerable to WBAN because the radiation emitted by the sensors implanted or worn on their bodies. The idea of load allotment was developed for the temperature organizes apparatus. Some of the nodes, however, are overburdened, resulting in a precipitous decline in their energy levels. Temperature-aware routing protocols were also presented. If the intermediary node's temperature is too high, both of these protocols will begin looking for another route [21].

Several strategies are proposed, each employing a different strategy that aims to keep up with the demands of modern routing design. Energy Harvested Aware Routing Protocol (E-HARP) was proposed for WBANs. E-HARP embraces two sink nodes and fourteen sensor nodes of varying types placed strategically over the human body. The cooperative effort in routing and the dynamic choice of Cluster Head (CH) underpin this protocol [22]. Several elements, such as the amount of power needed for transmission, the SN's residual energy, the total network-energy-loss, and the Signal-to-Noise Ratio (SNR) of the communication link, affect the final price tag, which in turn affects which Cluster Head (CH) is chosen [23]. In order to conserve the power of the source nodes, the protocol aids in data routing by blocking the transmission of duplicated data. Energy efficient Harvested Aware clustering and cooperative Routing Protocol (E-HARP) gets around problems associated with node energy consumption and dynamic Cluster Head (CH) selection. While using a double sink might prevent memory consumption from redundant data, doing so requires extranet labor costs and a technique of preserving data packets in Source Node (SN) [24].

The Energy-Aware Load-Balancing Routing Protocol **(**ELRW) was proposed in [25], and in this setup, there is one sink node and eight source nodes. Multiple factors, including as network eminence, distance to the sink, Residual Energy (RE) of node, and amount of hops, are integrated into a new path cost function. Each parameter's relative importance in determining the next hop is determined by its weight element. The power-saving option was integrated into the existing optimized link-state routing protocol. In this approach, a node is treated as a forwarder node if it has adequate energy for second-hop communiqué; otherwise, it is placed into a light or deep sleep state, depending on how much energy it has left. An energy efficient model and path loss approach (PLEEM) was presented [26]. In this setup, the packet is send to the sink-node when the Source Node (SN) is located close to it. If not, the Source Node (SN) employs a transmission method involving many hops.

The Energy Harvested and Cooperative Enabled Efficient Routing Protocol (EHCRP) was proposed in [27], and 8-sensors and 2-sink-nodes are activated by this technique. The next path is chosen based on a number of factors, including the Received Energy (RE), Signal-to-Noise Ratio SNR, Node Congestion Level (NCL), and the distance to the sink. In order to conserve the power of the source nodes, the mechanism implements Source Node (SN) assistance in data routing by blocking the transmission of redundant data. More power is supplied, and the lifespan of the network is increased, thanks to energy harvesting. Energy Harvested and Cooperative Enabled Efficient Routing Protocol (EHCRP) improves the network's energy efficiency and makes it last longer. To avoid SN's memory being overrun by redundant data, however, double sink deployment necessitates additional network expenditures and a method of preserving data packets.

In order to facilitate multi-hop communication in WBANs, authors [28] devised an effective forwarder-node collection strategy. The end-to-end latency and energy utilization balancing requirements for quality-of-service are met with the help of these settings. Extensive simulations revealed improvements in data packet forwarding, energy usage, packet delivery ratio, and End-To-End Delay EED when compared with specified protocols. In [29], a new Relay-Based Mobile and Thermally-Aware Routing Protocol (RTM-RP) for WBANs is described. High temperatures and energy usage are two of its primary targets. It's put to use in situations when freedom of movement is an absolute must. Energy-Efficient, dependable, and stable-routing protocol was presented in [30]. By conserving the energy of the network's nodes, this protocol extends the system's lifespan. An objective model is employed for this, one that favors low-energy routes with reliable connections.

Previous research into the routing techniques of WBANs shows that some of them do not account for priority in their routing data, while others directly send the emergency data, which results in higher energy consumption when the nodes are far from the sink. However, most of these investigations lacked energy harvesting mechanisms to permit recharging the SNs' batteries and ensuring sustainable-energy, hence their findings were largely inconclusive. As a result, we suggest a stable technique that requires less energy and ultimately increases the WBANs' network lifetime.

3. Experimental Design

a. Model construction

The suggested clustering protocol Energy-Efficient Multi-Factor-Based-Clustering-Approach (2EMFCA) relies on several different working models, such as the network model, the energy utilization &energy harvesting approach, to create the necessary operating environment for its development. This section provides a quick overview of these models.

Sensor network model:

Energy harvesting abilities for WSN are built into the nodes in the proposed design. Each node is fitted with an Energy Harvesting Unit (EAU) and linked to a Base Station (BS), where there is an endless supply of power. In this configuration, every node can take on the dual roles of Cluster Head (CH) and regular member node [31].

Energy consumption model:

Several models for radio communication's energy use have been proposed in the literature. However, the "first-order radio model" has been used throughout this investigation because of its usefulness and ease of implementation in the proposed method. Using equation (1), we may approximate the total amount of energy E_{Total} used for data transmission, reception, and aggregation [32].

$$E_{Total} = E_A + E_B + E_{Agg} \quad \text{Eq. (1)}$$

Where, E_A and E_B represent the power used throughout data packet broadcast and reception, respectively, and E_{Agg} represents the power used by a node during data packet integration.

Energy harvesting model:

Energy harvesting allows sensor nodes to draw power from their environment. Time periods where energy harvesting is possible are not constant. E_{Har} (i, r) represents the quantity of energy that a SN i has stored in its batteries over the course of a particular round r. The "Exponentially Weighted Moving Average" (EWMA) is a popular prediction model used to forecast the quantity of energy gathered by a sensor node. Sensor nodes in an Exponentially Weighted Moving Average (EWMA) network are expected to rely on solar energy collecting. As can be seen in Figure 2, EWMA keeps track of the harvested power by a node on a 24 hour basis. The suggested strategy is based on the premise that sensor nodes can continuously capture solar energy. Figure 3 depicts a basic energy harvesting model developed from a EWMA prediction model, which is used because of its simplicity and applicability to the proposed strategy. Equation (2) is the energy design of a SN.

$$E_{Curr}(i, r) = E_{Curr}(I, r\text{-}1) + E_{Har}(i, r\text{-}1) \quad \text{Eq. (2)}$$

Where, $E_{Curr}(i, r)$ is the full current energy of node i at the initial round r, while $E_{Har}(i, r\_1)$ is the quantity of harvested-energy by a node in prior round the (r _ 1).

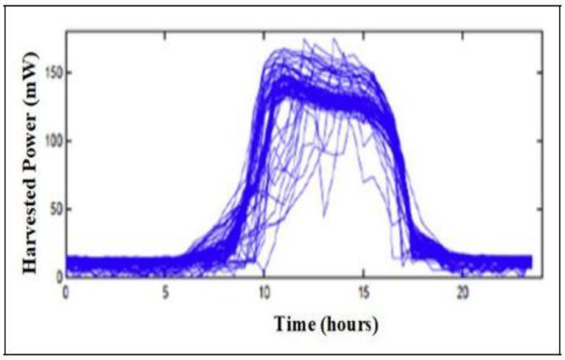

Figure 2 Rate-of-Energy Harvesting by Source Node (SN)

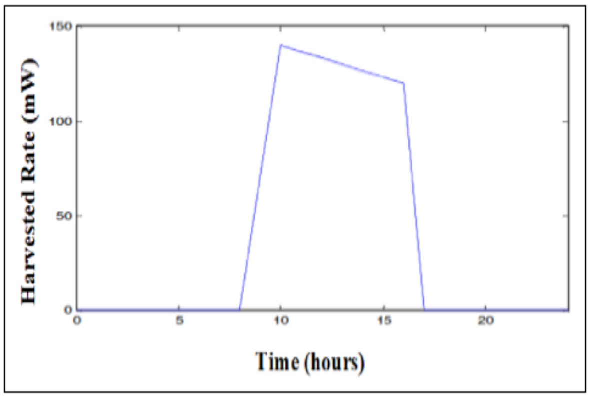

Figure 3 Simplified Design for Energy Harvesting

b. Proposed design

The problems with energy harvesting WSNs are addressed in this paper by proposing an "Energy Efficient Multi-Attribute Based Clustering Scheme."

- Energy constraints lead to instability in some CHs.
- The weakening of connectivity amid member-nodes & CHs as a result of noise in those areas.

The suggested strategy prioritizes these challenges by maximizing network throughput, minimizing end-to-end delay, and extending network lifetime. The clustering method and node selection that this strategy uses to attain its aims are described in detail below. The criterion for choosing a Cluster Head (CH) takes into account factors like optimal energy consumption and stable communication between nodes and Cluster Head selection (CHs) in the network. A node's link eminence in terms of Signal-to-Noise Ratio (SNR), neighborhood density, and residual energy are all examples of such characteristics. Each candidate node's weighted election value (EW) is determined using a weighted function, and this is then used to choose which node should play the Cluster Head (CH) role. In a given cycle, the Cluster Head (CH) is the node inside each cluster with the greatest Election Weight (EW) value. The steps of the proposed protocol's operation are discussed in detail here.

Deployment phase

The suggested protocol begins operating after all sensor nodes are planted at random in the intended field. The baseline power, storage, and computing capabilities of these nodes are all consistent across the board. Additionally, each sensor node has energy harvesting capability to guarantee a backup supply of energy. Once the sensor network model mentioned in section ''Sensor network model'' has been successfully deployed, the Base Station (BS) sends out a begin message (Begin_Msg) to all of the Sensor Nodes (SNs) (N1,N2,N3,...,Nn). When a node receives the Begin_Msg, it starts the next phase after determining its expanse from the Base Station (BS) dependent on the received signal strength.

Initialization phase

In this stage, communication between the two designated sink nodes begins with the transmission of Hello messages. After that, all of the other SNs in the system send their own Reply-messages. This communication serves four purposes: it informs each node in the network on its (1) neighbors, (2) alternative paths to the sink-node, (3) current location of the sink-node, and (4) corresponding cluster head (CH. Each Hello packet, as depicted in Fig.4, includes data about the source node's identifier (IDn), the destination node's identifier (IDst), the distance (in bytes) between the two nodes (d(n, Dst), and the source node's total energy (E_{Total}n), among other things. It is the sum of a node's E_{Curr} residual energy and its E_{Ha}r harvested energy. By solving for d(n, Dst) in Equation (3), we may determine the distance between any given set of sensor nodes (SNs).

$$d(n, Dst) = \sqrt{(X_n - X_{Dst})^2 + (Y_n - Y_{Dst})^2} \quad \text{Eq. (3)}$$

Figure 4 Hello & Reply Packet System

Destination (ID_{Dst})	Source Node (ID_n)	Node Location		Distance (n, Dst)	TotalEnergy (E_{Total})
		Latitude	Longitude		

Cluster Formation

Clusters in wireless sensor networks typically have their own Cluster-Head (CH) in charge of coordinating the activities of all nodes within that cluster and balancing the load on the network's single sink node. As a result, two groups are formed, with their own dedicated CHs, in this configuration. By default, S1 & S2 are each assigned as the Cluster-Head (CH) for their relevant groups. To prevent collisions in the shared media after designation, both Cluster-Head selection (CHs) use the CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) access mechanism to send commercial content to all Sensor Nodes (SNs). All Sensor Nodes (SNs) (non-CH) must be running in active mode to pick up the broadcast. Each sensor node that isn't a Cluster-Head (CH) registers with a specific Cluster-Head

(CH) based on the advertisement's Line-of-Sight (LoS) and uppermost RSSI data. If the first two criteria are equally important, the sensor node will join the Cluster-Head (CH) at random. In their roles as the Cluster-Head (CH), sinks S1 and S2 collect data from all the sensor nodes in their respective clusters, combine it with other data, and send it on to the AP. Figure 5 shows a cluster selection diagram.

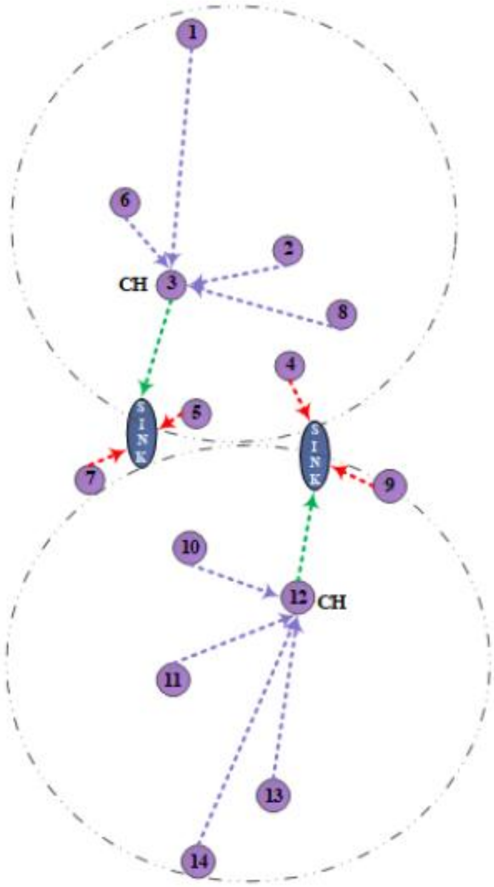

Figure 5 Cluster Head Selection and Communique

Node suitability as cluster-head (CH) is determined by four factors: current energy (E_{Curr}), energy Harvesting-Rate (HR), neighbor-node-density (DN), and Signal-to-Noise Ratio (SNR) of a node. To determine a node's Election Weight (EW), these factors are integrated in a weighted function. The node with the greatest Election Weight (EW) becomes the Cluster-Head (CH) for that area. For a given node i, the Election Weight (EWi) is determined in two distinct ways, the first of which is specified by equation (4). Details of the protocol are provided below.

$$EW_i = \begin{cases} DN_i \times \gamma_1 + SNR_i \times \gamma_2 , if\ r = 1 \\ DN_i \times \gamma_1 + SNR_i \times \gamma_2 + E_{Curr} \times \gamma_3 + HR_i \times \gamma_4, if\ r > 1 \end{cases}$$

Eq. (4)

In this case, the weight parameters are defined as $\gamma_1 + \gamma_2 + \gamma_3 + \gamma_4 = 1$. The parameter weight $(\gamma_1, \gamma_2, \gamma_3, \gamma_4)$ can be changed to suit the needs of the network.

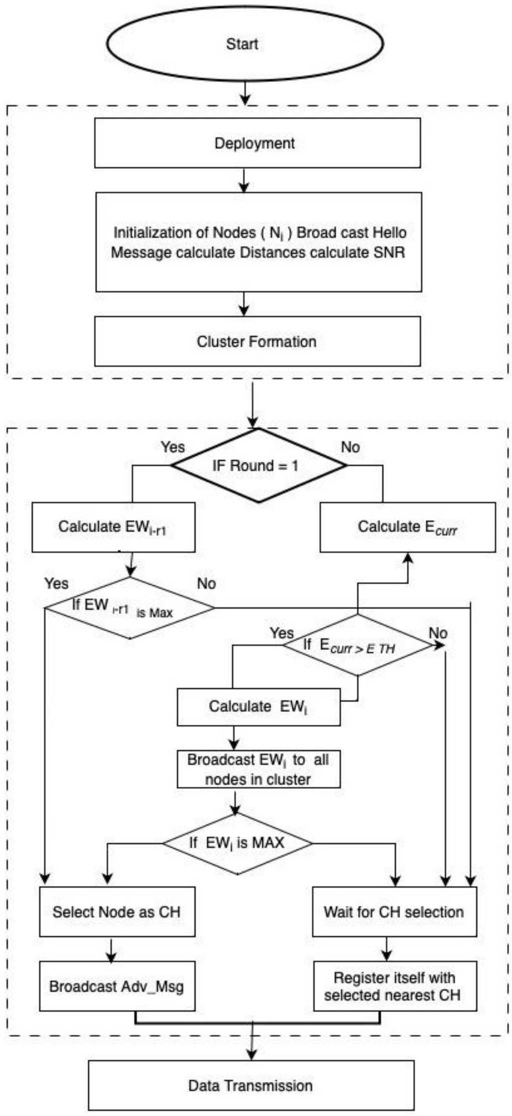

Figure 6 Flow Diagram of the Proposed Approach

After all of the capable nodes have determined the value of Election Weight (EW), they broadcast it to all of the other nodes in their radius. Each node evaluates its Election Weight (EW) against the data it receives. Nodes in the current cluster that have the highest Election Weight (EW) declare themselves Cluster-Head (CH) for the round. The chosen Cluster Head selection (CHs) will then send out an advertisement message, prompting all nearby nodes to make a join request. Figure 6 depicts the pseudo-code and flowchart for the proposed scheme Energy-Efficient Multi-Factor-Based-Clustering-Approach (2EMFCA).

4. Results And Discussions

This segment contains the simulation outcomes used to evaluate the proposed scheme's performance. This system is verified by comparing its outcomes to those of more current protocol proposals in the literature.

4.1 Evaluation parameters

Multiple parameters, of which a brief summary is provided below, are used in the evaluation and comparison with alternative systems.

Network lifetime (NL)

The lifetime of a sensor network is the time span from when the first node is activated until the final node dies. A larger number of iterations is indicative of a longer network lifetime [33].

Number of alive & dead nodes

The fraction of a network's nodes are whose energy reserves have not yet been depleted enough to prevent them from functioning normally. The remaining NL is represented by the amount of active nodes across all phases of network operation. Dead nodes in the network that have run out of juice and are now useless. This total is tracked across multiple rounds. A round's remaining lifetime and the rate at which sensor nodes are dying can be inferred from the number of dead nodes [34].

Energy-consumption

The amount of energy used by every node is calculated using the remaining power from the sensor nodes from previous rounds. It represents the sum of a sensor node's roundly energy gathering and consumption.

Stability period

Network stability refers to the time span between when the network is first set up and the first node dies. Throughput and performance are maximized in a network with a long stability period.

4.2 Simulation Results

Experiments on homogeneous WSN were conducted by simulating the Low-Energy Adaptive Clustering Hierarchy (LEACH) [35], Energy Efficient Clustering Protocol to Enhance Performance of Wireless Sensor Network (EECPEP-WSN) [36], Clustered Protocol for Heterogeneous WSNs With Solar Energy Supply (CHSES) [37], and Energy-Efficient Multistage Routing Protocol (EE-MRP) [38] protocols in the NS2 tool using the identical network parameters. Simulation results were compared to determine where the suggested scheme Energy-Efficient Multi-Factor-Based-Clustering-Approach (2EMFCA) differed from the aforementioned protocols in terms of performance. The effectiveness was compared using several metrics, including the percentage of nodes that died, the amount of energy left in the nodes that were able to recover, and so on. The remaining text of this section details the results of an examination of the proposed scheme's performance with respect to network lifetime, energy consumption, and throughput.

Network lifetime

The ratio of dead to live nodes throughout all cluster rounds is a measure of the network's lifespan. This value goes up and down as more and fewer rounds are played. As more rounds are played, the amount of dead nodes enhances and the NL is shortened for all sensor node schemes. Figure 7 shows that the initial node in Low-Energy Adaptive Clustering Hierarchy (LEACH) dies on round 745, but in other protocols it does not succumb until round 1000 or later. In EE-MRP and EECPEP, however, the first node dies in the 1180th and 1389th rounds. Clustered Protocol for Heterogeneous WSNs with Solar Energy Supply (CHSES) and Energy-Efficient Multi-Factor-Based-Clustering-Approach (2EMFCA) outperform competing protocols because of their superior energy harvesting capabilities, which allow them to recover some of the energy they use.

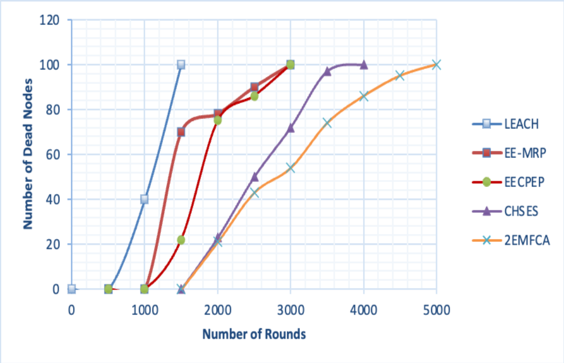

Figure 7 Contrast of Number of Dead-Nodes in Terms of Rounds

Number of surviving nodes

Another indicator of the network's durability is the proportion of nodes still operational after a given number of cluster rounds. Figure 8 depicts a comparison of the proposed protocol's number of surviving nodes to that of previously-existing systems. The results reveal that our suggested protocol has a relatively high number of surviving nodes. Clustered Protocol for Heterogeneous WSNs with Solar Energy Supply (CHSES) and Energy-Efficient Multi-Factor-Based-Clustering-Approach (2EMFCA) protocol sensor nodes, on the other hand, lasted for longer due to their optimal clustering mechanism and reliable energy supply. Both protocols worked perfectly up until the 1600th round with all nodes active. After this point, the percentage of Clustered Protocol for Heterogeneous WSNs with Solar Energy Supply (CHSES) nodes still functioning dropped to zero at the 4000th round, far faster than in Energy-Efficient Multi-Factor-Based-Clustering-Approach (2EMFCA). However, because it took link statistics into account for its clustering process, Energy-Efficient Multi-Factor-Based-Clustering-Approach (2EMFCA) kept running until the 5000th round.

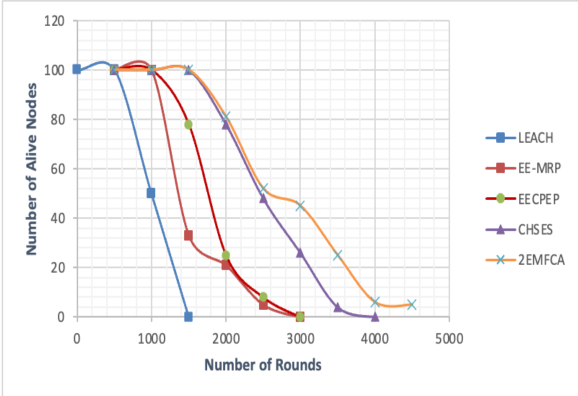

Figure 8 Contrast of Number of Alive-Nodes in Terms of Rounds

Network RE

Figure 9 displays a contrast of the average residual energy in a network vs time (in seconds). For the simulation's parameter setup, each node is given 0.5 J of energy, for a grand total of 50 J for 100 nodes. The figures unambiguously demonstrate that the proposed procedure has the lowest energy dissipation of any of the tested methods.

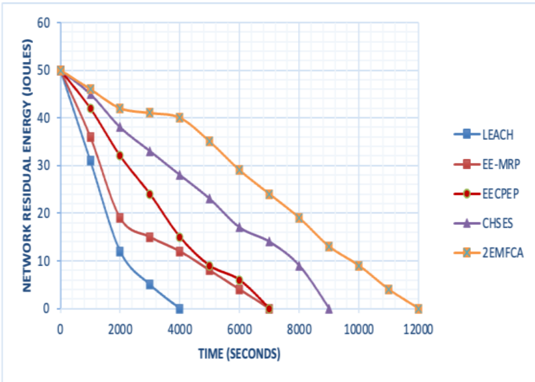

Figure 9 Contrast of Network Residual Energy

Network throughput

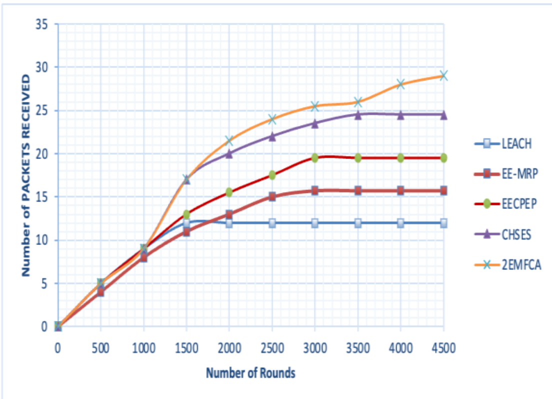

Figure 10 Contrast of Overall Network Throughput

The throughput of a network is measured by the number of packets that have arrived at their final destination. Figure 10 shows the throughput comparison of the proposed protocol to the other discussed techniques. This graphically represents how the throughput of most algorithms is roughly the same for the first 1000 iterations and thereafter increases at about the same rates. This is because in the beginning of a network there are zero or very few dead nodes.

Network stability period

From when a network is first set up until the first node dies is known as the stability phase. The stability period of a network is crucial to ensuring continuous, high-quality data transmission and the smooth running of the network as a whole. The proposed protocol has the longest stability period among the protocols under study, as demonstrated in Figure 11 of the simulation results. The network in Energy-Efficient Multi-Factor-Based-Clustering-Approach (2EMFCA) ran for 1680 rounds before the initial node died, demonstrating the protocol's superior performance compared to the others. The assessments confirm that the suggested strategy outperforms the alternatives in each category. It is important to note, however, that the suggested technique broadcasts a large number of messages throughout the cluster creation and cluster head (CH) selection phases. As a result, the suggested approach incurs more message broadcasting overhead than alternative approaches.

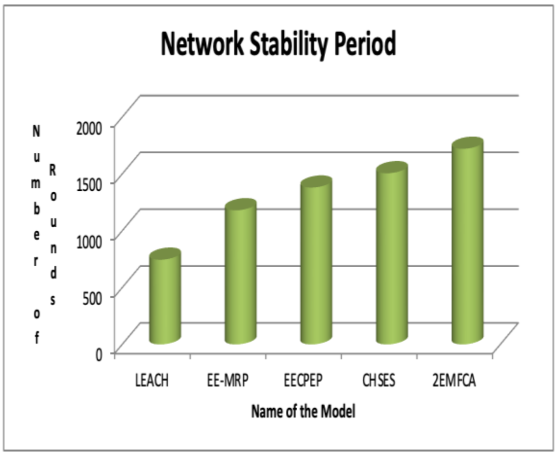

Figure 11 Network Stability Period with Respect to Rounds

5. Conclusion And Future Works

Power management in sensors and network longevity are two of the biggest obstacles to overcome while building routing protocols for WSNs. In this context, increasing the rate at which packets are reliably sent to the Base Station (BS) is dependent on achieving the longest possible period of stability. The proposed clustering protocol relies on a parameter, Election Weight (EW), which depends on a number of sensor node characteristics, including current energy, EHR, amount of neighbor nodes, and eminence of the link with respect to environmental noise. The first three values guarantee that a sensor node uses and conserves energy in a sustainable manner. Finally, the last argument guarantees that weaker links are not used for inter-node communication. With this improvement, fewer data packets will be lost along the transmission line. It helps save power by decreasing wasted effort recovering lost data from transmission failures. The network's stability and throughput are improved for the longest possible time with this method, and the overall residual energy is reduced.

As was said previously in the article, the proposed approach in this study was meant to be tailored for WSNs that, once deployed, have a static sensor node. Future work might expand the suggested protocol to accommodate Sensor Nodes (SNs) and IoT tools in a mobile setting. The suggested protocol should also minimize the overhead associated with other QoS factors, such as fault lenience and message dissemination.

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