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REVUE EUROPEENNE D ETUDES EUROPEAN JOURNAL OF MILITARY STUDIES
Social Science Journal

Enhancing WSN Energy Efficiency through a Novel Power Aware Hierarchical Cluster Based Routing (PAHCR) Protocol

By

P. Ponsekar
Ph.D Research Scholar, Department of Computer Science, Kovai Kalaimagal College of Arts and Science (Autonomous), Affiliated to Bharathiar University, Reaccredited With 'A' Grade by NACC, Coimbatore - 641109, Tamil Nadu, India

Dr. M. Sengaliappan
Associate Professor and Head, Department of MCA, Nehru College of Management, Affiliated to Bharathiar University, Nehru Gardens, Thirumalayam Palayam, Coimbatore - 641105, TamilNadu, India

Abstract

According to its energy limitations, scaling is a fundamental design consideration inside the "Wireless Sensor Network (WSN)". Too many "Sensor Nodes" (SNs) in a WSN with a single layer of architecture might cause the gateway SN to become overloaded, leading to poor responsiveness and inaccurate event monitoring. Single-tier WSN designs that use a higher number of SNs to encompass a bigger region of activity are mostly not scalable. The WSN can be scaled without compromising on service with the help of certain routing algorithms that organize SNs into clusters. To improve WSN's energy efficiency, in this research we develop a new protocol called "Power Aware Hierarchical Cluster Based Routing (PAHCR)". Regarding large-scale WSNs, it functions as a self-organizing characteristic among SNs. Each cycle in the existing protocols uses more energy than necessary due to the "Cluster Head (CH)" choosing as well as the rerouting procedure. The proposed PAHCR protocol has the potential to minimize this energy depletion. Each cluster in a WSN is given a distinct identity by this protocol, and that identity serves as the transmission's "next hop". The CHs are also not picked at randomness but rather are chosen according to their "Residual Energy (RE)". The "Cluster Identity (CI)" is sent from the outgoing CH to the incoming CH at the start of each cycle. The proposed protocol minimizes energy usage as well as extends WSN's lifespan by performing both the cluster creation and routing phase simultaneously during network configuration. Considering performance metrics including "Energy Efficiency", "Packet Delivery Ratio", "Throughput", and "Routing Overhead" within WSN, we evaluate and compare the proposed PAHCR protocol's performance with that of the already-existing E-BEENISH and DOR protocols.

Keywords: Wireless Sensor Networks, Energy-Efficiency, PAHCR, DOR, E-BEENISH

1. Introduction

Nowadays, the WSN is deployed mostly as a primary wireless channel in a wide variety of fields, including but not limited to smart buildings, environmental sensing, industrial, the Internet of Things, etc. Since it is inexpensive, compact, and simple to implement, it serves as a promising revolutionary innovation for use in practical systems [1].

The various circumstances for its implementation influence the WSN architecture. Message transmission is the primary issue of WSN architecture in smart home devices and industrial purposes when energy does not pose a barrier. However, in resource extraction and other emergency conditions where batteries cannot be replaced or recharged, extending the WSN lifespan is of supreme concern [2].

As another important factor in WSN architecture, the scale of its operational region is often taken into account [3]. For short ranges, the SNs communicate with the "Sink Node (SiN)" or "Base Station (BS)" effectively by sending packets. Conversely, in a vast region, packets were routed thru the many intermediary SNs before arriving at the SiN. There are many 3 primary obstacles to overcome when constructing a WSN for a vast area: partitioned environment, quicker mobility, and energy savings at relay SN [4].

Clusters constitute smaller sub-regions that have been created when a larger territory is subdivided. Within those clusters, a single SN acts as the CH, gathering information from the other SNs before sending it to the following SN or SiN [5]. There have been numerous suggested methods for cluster creation in WSN, including SEP, MLEACH, and LEACH [6]. By selecting CH from SNs, those methods extend the longevity of WSNs and make effective use of their energy resources.

There are 2 main approaches to routing: "Flat Routing", and "Hierarchical Routing". When using "Hierarchical Routing", data is first sent from the SN to the CH, and then from the CH towards the subsequent CH, however when using "Flat Routing", only the path between the SN and SiN is considered [7].

Once all intermediary SNs have adequate power to receive packets and forward them towards the following SN, then would be the route regarded to be open. These intermediary SNs serve as relay SNs, and the mechanism is called Relaying. If these SNs run out of energy, relaying cannot continue. The SNs closest to the SiN or BS are the ones most likely to be employed as relays, which drain their batteries quickly. As a result, these SNs die, and a "Warm Hole Region" of dead SNs forms in the vicinity of the SiN. Because of this, choosing the best possible path is a crucial part of designing WSNs [8].

Problem Statement

When it comes to WSN, an SN is made up of a "Radio Transmitters and Receivers, Processor Unit, Sensor Unit, and Battery Unit". The energy-intensive parts of the SN are the "sensors, the processors, and the receivers and transmitters". Sensing energy is defined as the energy required to sense quantitative measurements, such as heat, gases, moisture, etc. Relatively, sensing uses less energy compared to any other power usage component [9]. The processor processes sensed information like heat, gases, moisture, etc., and turns these into packets, that are then sent to the SN's transmission module. Information that comes from many different SNs is typically processed by the processor, and then either stored or sent to the subsequent SN. The node's energy consumption is primarily driven by its transmitting and receiving modules. One of the most important factors within the radio model of power usage is the range over which a signal must be sent. The power required to keep traveling grows exponentially when the range is beyond a certain point. So, clustering or minimal range protocols should be employed in the WSN architecture for energy-efficiency throughout the transmission of packets [10].

Paper Contribution

In this research, we proposed a new PAHCR technique to address the aforementioned issues. The suggested protocol contains two stages of operation: the "Setup Stage (SS)" and the "Steady-State Stage (SSS)". Initially in SS, the SNs were grouped into clusters. When in the next SSS, data is sent from SNs to the BS. Incorporating the clustering approach into the data collecting and distribution process helps cut down on the overall energy needed for the operation. To take full use of this benefit, the proposed PAHCR groups SNs together into distinct clusters. By accumulating the transmission of lower-energy SNs inside the cluster, the technique often chooses the SN well with the highest energy as the CH. The proposed PAHCR protocol effectively controls energy usage by making use of the SNs during multi-hop connectivity inside a specific cluster and minimizing transmissions to the SiN. Routing and SN's behavior in the multi-hop and multi-level contexts are based on the HCR approach and diverge most sharply from one another.

Paper Organization

Section 2 discusses the latest literature on energy-efficient protocols for WSN, Section 3 provides brief descriptions of the methodologies used in the development of each proposed and existing protocol, Section 4 compares and contrasts the obtained results using these protocols, and Section 5 concludes the article with an outlook on possible future research directions.

2. Related Works

In [11] the researchers suggest a "Gateway SEP (G-SEP)" to cut down on the additional energy usage by placing a "Gateway Node" in the hub of the WSN and putting the BS in a remote location. This protocol takes into account the RE of the most sophisticated SNs in addition to their proximity and means proximity to the BS when deciding which ones to use as CHs.

To avoid accumulated uncertainty in continual information forecasts, the researchers of [12] presented an "ECR" system based on a "Two-Vector" framework to synchronize anticipated information in the "Intra-Cluster" communications. It develops prospective information approximating and calculates its forecast cutoff deviation during the SS of the data collecting cycle. The ECR concept is a compact and extensible information model that predicts which does not necessitate any preexisting data structures. It improves efficiency by decreasing the number of transmitting data rounds and the amount of energy used without compromising precision, but it is very difficult to implement.

The "DGAST" technique developed by the researchers in [13] collects SN input at regular intervals and splits up the WSNs into cycles. There are 4 phases in each DGAST cycle: data gathering, aggregation of data, chosen communications, and adjusting the sampling frequency for SNs. Although DGAST requires sophisticated calculation and significant memory consumption, it saves energy and increases the lifespan of periodic WSNs.

In [14] the researchers have presented a "Kalman filter" method for compressing data. The "Data Reduction" and "Data Prediction" stages of this technique are responsible for the actual data compression. There is a significant processing cost and it doesn't take into account clustering topology and WSN scaling, however this method of data compression is productive and efficient, dependable, energy saving, and increases the lifespan of WSNs.

For three-tiered heterogeneous WSN, the researchers of [15] presented a hybrid technique they called "Distance Aware Residual Energy-efficient SEP (DARE-SEP)". DARE-SEP prioritizes SNs that seem to be closer to the BS and have a better RE when determining which SN will serve as the CH. Moreover, the reported findings do not conduct a detailed investigation into the ideal choice of the weighting factor, which has a major impact on the system's effectiveness.

3. Methodologies

3.1.DOR Protocol

This section describes the "Clustering Based Dynamic Optimized Routing (DOR)" existing protocol for WSNs, which may be used for regular data gathering. While using this method, the whole WSN region is partitioned into "Cluster Regions (CR)", with each CR housing a unique CH. The CH could be able to communicate with the BS more efficiently using this approach. Within the clustering, the SNs respond to the "hello" signal sent by the BS at a predetermined amount of energy to verify their presence and determine their relative location. In particular, the retransmission's RE may be used by the SNs to determine the range between their location and the BS. Utilizing signal computation, the SN may determine the optimal power for communicating with the BS. The steps involved are as follows: After deciding on a CH, the clusters must be created before any transmission of data can begin. During the CH screening process, the approach prefers autonomous CHs with hidden control logic. As a result of cluster formation, the SNs located just below the CH are grouped [16].

3.2.PAHCR Protocol

By clustering them together, the SNs are easier to manage, and the "Hierarchical Cluster Based Routing (HCR)" protocol designates a single SN within every cluster to serve as the CH. The CH, as seen in Figure 1, functions as a channel between both the BS as well as the cluster's SNs.

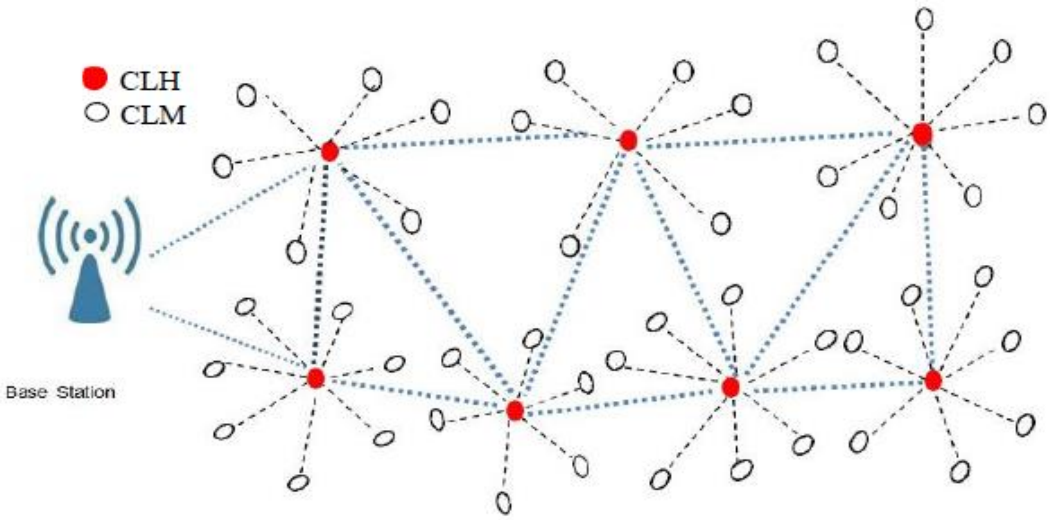

Figure 1. *HCR Model*

Furthermore, the model incorporates performance enhancements such as data fusing by establishing a threshold limit. The protocol's sleeping and idle pairing between SNs is taken care of by the conceptual models.

3.2.1. Cluster Identity (CI) based on HCR (CI-HCR)

Each stage of a clustering process in a routing technique often consists of its distinct stages. The protocol maintains a "Routing Table (RT)" which may well assist in selecting or replacing CHs after each stage of operations. Energy usage together at SN, as well as route levels, is certain to peak at some point during CH choosing procedure. That's because the CH choice requires a large number of command packets to be sent down the connection among the cluster SNs.

To conclude the task, this procedure must be continued many times, resulting in peak SN power usage. Using CI rather than CH identity to keep the routes up-to-date, could fix the previously noted issue. This method is useful for keeping RT over SNs operational despite having to recompute the routes.

Energy usage increases with each iteration of the CH choosing and re-routing procedure this CI-HCR will assist. Together all clusters throughout a WSN are given a "Unique Identifier" and this number is utilized as the transmission's "next hop" reference. The CHs aren't chosen at random, instead, it selects them primarily on its RE.

Each freshly chosen CH inherits the CI from the outgoing CH and passes it on to the incoming CH at the start of the following stage. WSN consumption of energy is decreased by around 19% and WSN lifespan is increased by roughly the same amount because all these cluster construction and routing stages are executed simultaneously upon WSN initiation.

After an SN is activated, its neighbors are used to determine the best path to the SiN, and this path is reevaluated immediately when there has been a modification to the network. The present protocols, on the other hand, regularly modify the path for every stage. CH recognition is used to determine the very next hop in the proposed protocol. In Figure 2, the CI-HCR Model is shown.

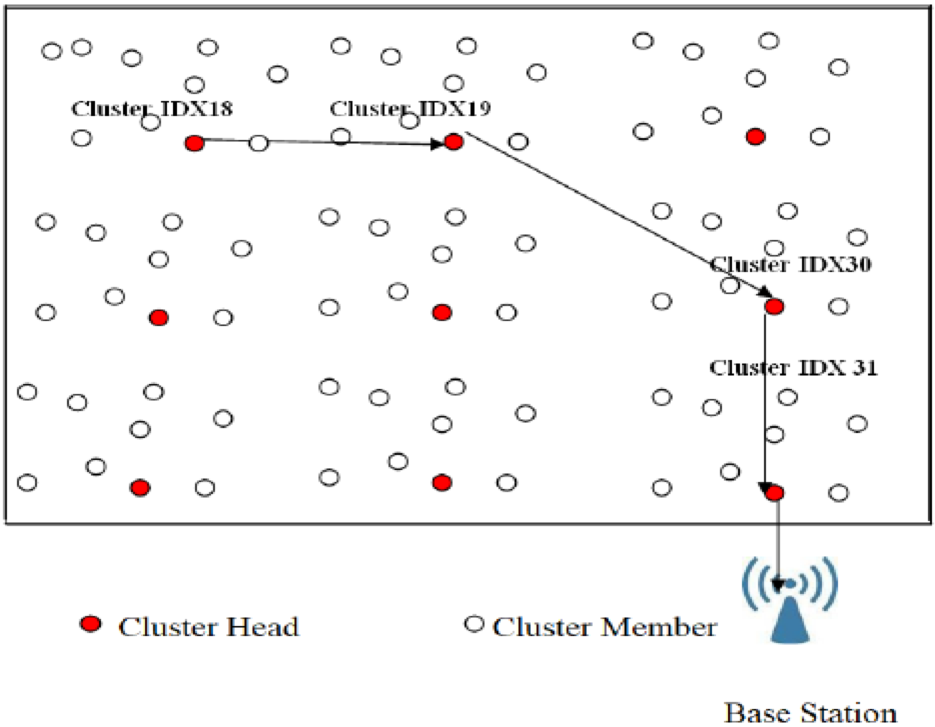

Figure 2. *CI-HCR Model*

A "Unique Identifier" is used in this procedure to track down each cluster. The RT transmission of data entry's next hop is determined using this identity. This technique involves every SN inside this cluster sending its sensing and collection data to its "CH x18". It is the hub from which information is gathered and transmitted to the neighboring "CH x19". It also sends the information to "CH x30", which leads it to "CH x31".

The information obtained by "CH x30" is sent on to "CH x31", which remains in closer proximity to the BS. The CH is responsible for keeping this CI token valid for as much as it indicates that they are the leader. Once all the stage is over, the token is transferred to the succeeding CH. The newer CH was chosen due to the RE it has. The CI-HCR reduces the amount of power needed to calculate the RT in each round.

Power Aware (PA) Optimization in CI-HCR:

- In CI-HCR, the CH picking and cluster creation are enhanced with the assistance of the PA method. Following the construction of a cluster, a CI-HCR route is established between CH and the BS.
- Together all clusters inside a WSN are given a "Unique Identifier," and this number is utilized as the transmission's "next hop" reference.
- The CHs aren't chosen at random; instead, participants choose them depending on their RE. Each freshly selected CH inherits the CI from the outgoing CH and passes it on to the incoming CH at the start of the following stage.
- At the end of each stage, the token is passed on to the CH who had the most RE at that stage.
- The use of CI-HCR would lessen the amount of energy that the SNs need to spend in the calculation of RT after each stage.

3.2.2. Multi-Hop Routing (MHR) based on HCR (MHR-HCR)

The proposed MHR-HCR constructs the HCR using a multi-tier system, wherein CHs are clustered and then picked from within a given cluster. Since the CH is located at the top of the tier and could communicate directly with the BS, this significantly extends the WSN's operational period. CHs were recognized as multiple hops enabling data transfer between neighboring levels. Lower-tier SNs can send data to higher-tier SNs through the latter's CHs.

The CHs relay the level-aggregated data to the subsequent level during inter-cluster routing. The information is then sent by the SNs to respective CHs, and finally by the CHs to the BSs. From the perspective of a SiN, this data transmission and "Data Aggregation (DA)" may be seen as a hierarchical DA. Communication amongst CHs is limited to specific occasion observances. The CH sends out a flood of data to all of its neighbors whenever it detects anything remarkable. Because of this, every CH will be aware of what took place and exactly where it occurred.

Once the CH has received a request from a mobile SiN located on the same local-grid, it will begin building a "d-tree". Specifying the transmitting zone with the locations of SiN's local-grid and interested-grid, it could reduce the data floods among all CHs, which necessitates broadcasts, to some degree. To draw a diagonal line starting from the longest distance point on the grid of interest to the corresponding farthest point on the SiN-grid, its beginning must be marked. Reducing the transmission of data duplication and preventing overcrowding and crash, are valuable. In a restricted attention system, the SiN will send the request packet to the closest CH.

The SiN's location and the CH's destination are both specified in the request packet that is sent from the SiN. The MHR-HCR forwarding zone's root is always the CH of its level which includes the SiN. Since the "d-tree" is built by the CH at each level, it can only be used inside that level's forwarding zone. The "d-tree" begins in the nearby CH and progresses upwards to the CH, the focus region of the interested-grid.

Messages are sent from the SNs to their CH, as seen in Figure 3. Following completion of the tier-3 internetwork, the CHs data transmission from DA to the higher tier-2 CHs is made.

Following DA processing at its level, tier-2 sends the information to tier-1, which in turn sends it to the BS.

Moreover, the MHR-HCR constructs and retains a cost-field in the forwarding zone, which the CHs use to determine how much it will cost to send the data to other CHs. Each CH may use the cost-field to calculate how much it will cost to send data to the SiN through its node.

The direction in which data is sent is determined by a comparison of the costs involved in sending the information from each CH to the SiN, with priority given to the path with the lowest total cost to the SiN. The receiving SN considers the packet's destination and transmission cost before deciding whether or not to send it. This allows it to bypass the RT and send the packet to any SN that can deliver it to the SiN.

The packet's cost-field determines which path the CH takes to send it on to the SiN, and the CH then transmits the packet along that route. SNs with a lower cost would continue forwarding the packet, whereas SNs with a larger cost will simply reject it, cutting off communication between that SN and the SiN. After the SiN verifies the interested-grid, it sends the request packet out to each of the other CHs, along with the associated cost-field. In an attempt to get to the CH of the interested-grid, the receiving CHs will rebroadcast the packet till it arrives at its destination.

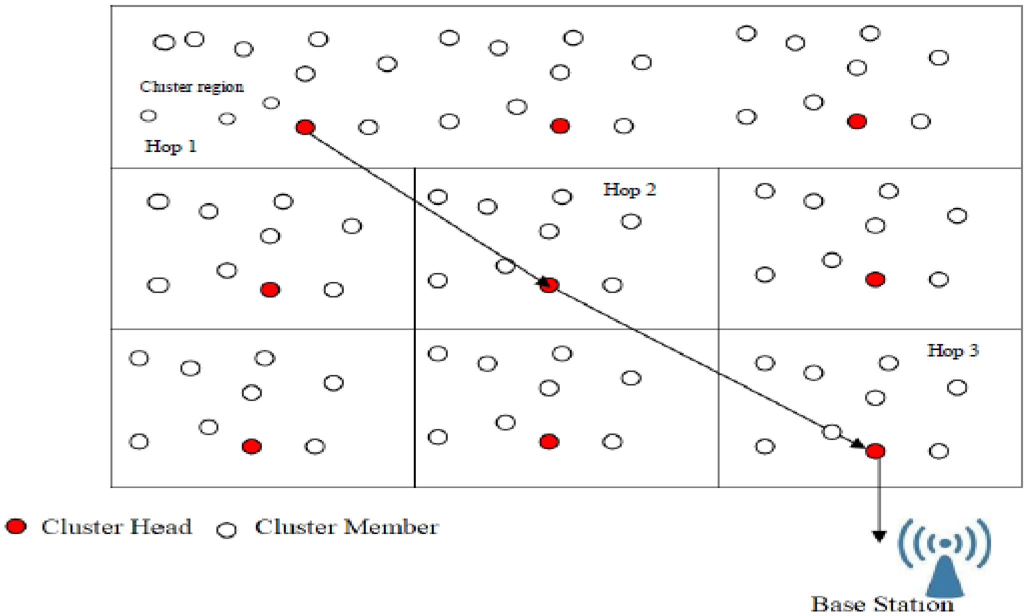

Figure 3. *MHR-HCR*

The SiN generates a cost-field, which may be seen as a separate object, with larger costs for SNs located far further from the SiN. The SiN initializes the cost-field to '0' and announces this change through an "Advertisement (AD)". The quantity of energy needed to send a packet from CH to SiN is defined by the integer inside the cost-field.

The CH starts with a "∞" starting cost. Let "$Cost_P$" and "$Cost_Q$" be the starting costs for the CHs "P" and "Q", correspondingly. After obtaining Q's "AD", CH Node "P" computes the connection cost "$Li_{Q,p}$" from Node "P" to Node "Q", and then joins this cost with Q's cost using the following Equation (1):

$$(Cost_Q + Li_{Q,P}) \quad Eq \rightarrow 1$$

In case of as per Equation (2):

$$Cost_Q + Li_{Q,P} < Cost_P \quad Eq \rightarrow 2$$

In such a case, it may use Equation (3) to handle the situation:

$$CostP = CostQ + Li_{Q,P} \quad Eq \rightarrow 3$$

Additionally, this keeps reconstructing the cost-field for nearby CHs.

If Equation (4) is not met, then P does not accept the AD packet and keeps the current connection established.

$$Cost_Q + Li_{Q,P} < Cost_P \quad Eq \rightarrow 4$$

The "d-tree" is built by repeating these steps between each of the networks. When a CH obtains an AD, it may choose whichever CH it wants to be its parent. When a CH gets AD from numerous sources, it checks its cache to see whether it has already sent the information. If the newly constructed CH "m" gets an AD from CH "n," it will consider "n" to be a possible parent.

Consider that when CH "m" gets a packet through downstream "k," CH "m" calculates the minimal cost route by comparing the cost across various parents. Furthermore, the CH "m" shifts its parent from "n" to "k" within the "d-tree".

Some CHs, known as "Substitute Cluster head (SC)s," don't have a link to the d-tree. The "Relaying Cluster head (RC)" refers to the CHs that have been linked to the d-tree. The SC is activated whenever the RC's energy is lower than the "EN_r".

Power Aware (PA) Optimization in MHR-HCR:

- MHR-HCR employs PA optimization for CH identification and cluster creation. Once clusters are formed, the path from CH to BS is defined using MHR-HCR.
- In the MHR-HCR, each CH belongs to a multi-tiered cluster from which a single CH is chosen to complete the HCR.
- Since the CH is located at the top of the tier and can interact directly with the BS, this significantly extends the WSN's operational period. CHs are recognized as multiple hops for data transfer between neighboring levels.
- Lower-tier SNs can send data to higher-tier SNs through the latter's CHs.
- The CHs relay the level-aggregated data to the next level throughout the inter-cluster routing. The information is then sent by the SNs to respective CHs, and finally by the CHs to the BSs.
- Data in SiN may be regarded as a hierarchical DA "d-tree", which allows for the level-wise aggregation and transmission of data. Communication amongst CHs is limited to specific occasion observances.
- The CH sends out a flood of data to all of its neighbors whenever it detects anything significant. Because of this, every CH will be aware of what took place and exactly where it occurred.

- When the CH gets a request from a mobility SiN within the same local grid, it immediately begins building a "d-tree" to respond to the request.

3.2.3. Multilevel Routing (MLR) based on HCR (MLR-HCR)

In contrast to MHR-HCR, MLR-HCR gives every CH a level throughout BS. The method offers a very efficient means of determining how to go from CH to BS. Also, it solves the issue of route reelection in the event of SN faults or even other faults.

The "Route Construction Phase (RCP)" and "Data Forwarding Phase (DFP)" describes the two stages of the method's operation. A packet called the "Route Construction Packet (RCPT)" is transmitted by the BS towards the SiN during the RCP to announce the packet's existence in the network.

The "Route Requests" are sent between the SiN and CH, or the CH and CH, to facilitate the spread of the packets. The data from the "Route Request Packet (RRPT)" is then used to construct the route. On every CH during an RCPT transmission, this method designates a separate intensity level. All of the SN levels are initially set to the maximum value, whereas all SiN levels including hop-calculate values were initially set to '0'. After receiving RCPT first from BS, the SiN modifies the packet with its identifier, hop-calculate, and level before broadcasting it to all the CHs in its direct proximity.

Upon receiving the packet from the SiN, the CH updates the packet information by increasing the sender level of the packet by '1'. In such a way the hop-calculate value of the packet increases every time it moves from one SN to another. At the same time, the level increases only when the packet is moved from one CH to the other.

The packet's level and hop-calculate are increased by '1' as soon as the CH receives the RCPT, the CH also uses the RCPT to update its RT. The CH then re-broadcasts the packet to its neighboring CHs. The same process is carried out at the received CH until the RCPT reaches all the CHs of the network. If the CH receives the RCPT from the same or lower level it discards the packet, it is to be noted that each cluster broadcasts the RCPT only once and maintains its own RT. This research focuses on creating an RT for each CH that consists of two fields, namely "Subsequent Hop" and "Path Cost".

The field "Subsequent Hop" holds the next hop address and the field path cost-field holds the value of cost incurred to reach the BS which is calculated as following Equation (5):

$$Path\_Cost = Sender\_Stage \times Hop\_Calculate \quad Eq \rightarrow 5$$

At the outset, each intermediary SN and along route verifies the sender level, whereas if values of the level are lower compared to its level, it adds one to the sender level and takes on that level, as illustrated in Figure 4.

After that initial step, the intermediate SN now computes the cost of the route towards the BS and updates the information in its RT using "Path Cost" and identification of the sender. Subsequently, the middle SN raises the value of sender hop count and updates the information of sender identification, hop calculation, and sender stage of RCPT, and it broadcasts the updated information to its neighboring CHs.

The SN then sorts its RT based on the "Path Cost" after broadcasting. If the sender stage is not less than that of the level of the immediate SN, the packet received from that level is dropped. Due to the limited memory availability in the SNs, it is assumed that the SN maintains only the first k-level entries of the RT as the next-hop and discards the rest of the entries. In case a regular SN operates as a relay SN among two CHs receive RCPT, the SN increments the hop count by one and forwards the packet to the subsequent CH.

It is quite uncommon for a BS to launch the RCP because it establishes several minimal cost shorter distance routes. However, it is also crucial to look at the SN's RE for every CH, since focusing solely on the shorter route and abandoning the energy would lead to the nodes all along the path running out of energy. As a result, fewer active SNs will only be available, lowering the chances that multiple pathways may be established.

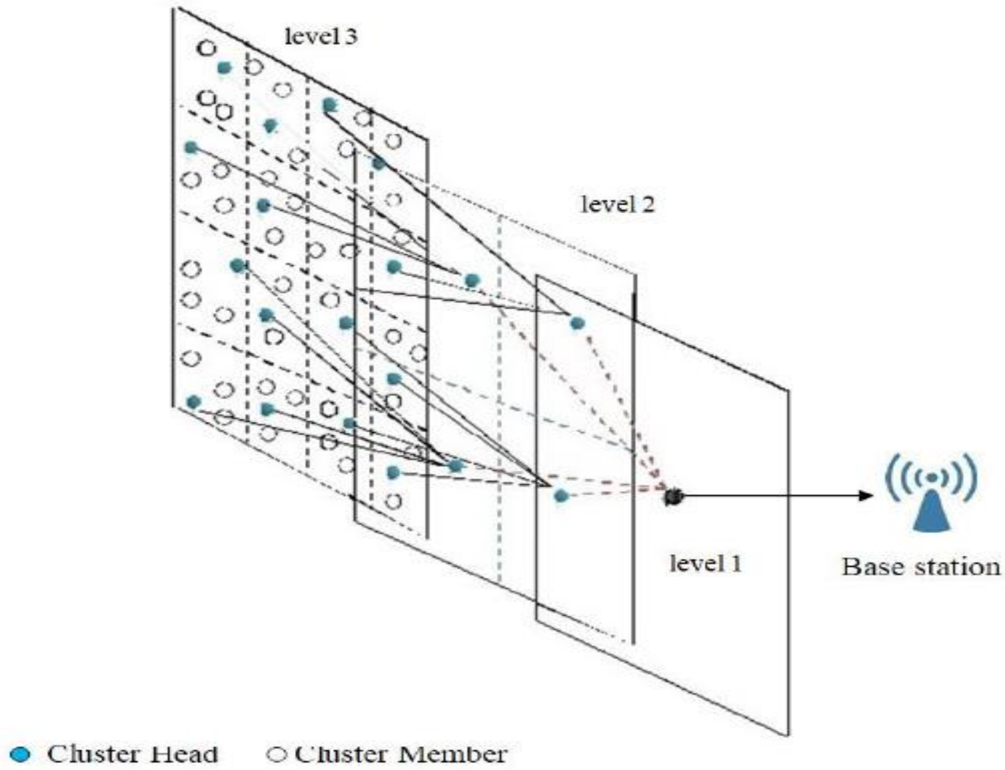

Figure 4. *MLR-HCR*

This bottleneck can be addressed by making the CH pick subsequent hop SN by first checking the RE of the subsequent hop SN. If the RE value of an SN at the next hop is greater than a certain threshold, then the SN is considered to have a higher level of energy. As a result, the CH will choose that specific route to the SiN. Through regular "hello packet" exchanges, the RE values of surrounding CHs are kept up to date. If an adjacent CH's RE drops below a certain threshold, it would no more function like a router to transfer data along a given path. It may instead function as a regular SN, transmitting its sensed information to the hop after it.

In case the CH detects that all of its subsequent hop SNs along the path have got their RE less than the threshold value, it is understood that they no longer act as a router in forwarding data. Upon receiving such a failure packet, a CH will reject the subsequent hop SN from its RT.

The CH stores the packet over a predetermined amount of time and watches for the subsequent hop to complete the transmission before releasing it. Whereas if CH gets a failed notification within that waiting period, it will infer that now the route via the following hop gets disrupted and will rebroadcast the packet to an alternative succeeding hop as from RT. By eliminating its inclusion from RT, it also eliminates the SN that transmitted the failed packet as its next hop. In the absence of a failed packet during the CH's waiting period, the CH will believe that the packet of data has been properly transmitted and will delete it.

However, if the originating CH has no other way of reaching the SiN after receiving a failed packet, it will advertise a request to the SiN to set up an RCP for the same CH by sending the RCPT once more.

Power Aware (PA) Optimization in MLR-HCR:

- The optimization process is used for cluster formation and CH election in this MLR-HCR. The packet dissemination involves Route-Request between either SiN to CH or CH to CH.
- Following receipt of the RRPT data, the route is constructed. When transmitting RCPT across a network, this optimization gives every CH its level option.
- The CH stores the packet for a particular amount of time and watches for the subsequent hop to complete the transmission before releasing it.
- Whereas if CH gets a failed message within that waiting period, it will infer that such route via the following hop is disrupted and will rebroadcast the packet to an alternative following hop as from RT. The SN which transmitted the failed packet is also removed from the list of following hops by deleting its item from RT.

4. Results and Discussions

Using networking measures like "Energy Efficiency", "Packet Delivery Ratio", "Throughput", and "Routing Overhead" throughout the WSN, the effectiveness of the already deployed E-BEENISH, DOR, and proposed PAHCR protocols are being evaluated. The research was conducted in a simulated environment, and from that environment, numerous cases were drawn. Table 1 lists the simulation settings used in this analysis. All of these protocols using the battery component to construct SNs were put through their paces in the Ns2 simulation model.

Table 1. *Simulation Parameters*

Parameters	Values
Data aggregation energy	5nJ/bit
Data packet size	1024 bytes
Network size	200 m ×200 m
Node initial energy	0.5 J
Transmitter amplifier where $d < do$	10 pJ/bit/m2
Transmitter amplifier where d≥do	0.0013 pJ/bit/m4
Transmitter circuitry dissipation	50 nJ/bit

4.1.Energy Efficiency

To measure energy-efficiency, compare the amount of energy required to produce a certain amount of communication to the amount of energy produced. An outcome to the problem of how to enhance energy-efficiency may be found in the efficient transport of specific data over a given amount of energy. Another word for energy-efficiency is "the use of less energy to provide the same function", which is a further generalization of the original definition. When applied to these scenarios, energy-efficiency is a key factor since it improves detection accuracy while maintaining the same level of power usage. Figure 5 and Table 2 show the energy savings achieved by implementing the E-BEENISH, DOR, and PAHCR. In this case, the proposed PAHCR in communication throughout the WSN with varying sizes of packets provides improves energy-efficiency.

Table 2. *Energy Efficiency*

Packet Size (Bytes)	E-BEENISH	DOR	PAHCR
20	90.32	96.43	98.12
40	81.23	92.32	96.09
60	72.56	88.78	94.43
80	63.54	84.12	92.04
100	54.65	80.12	90.04

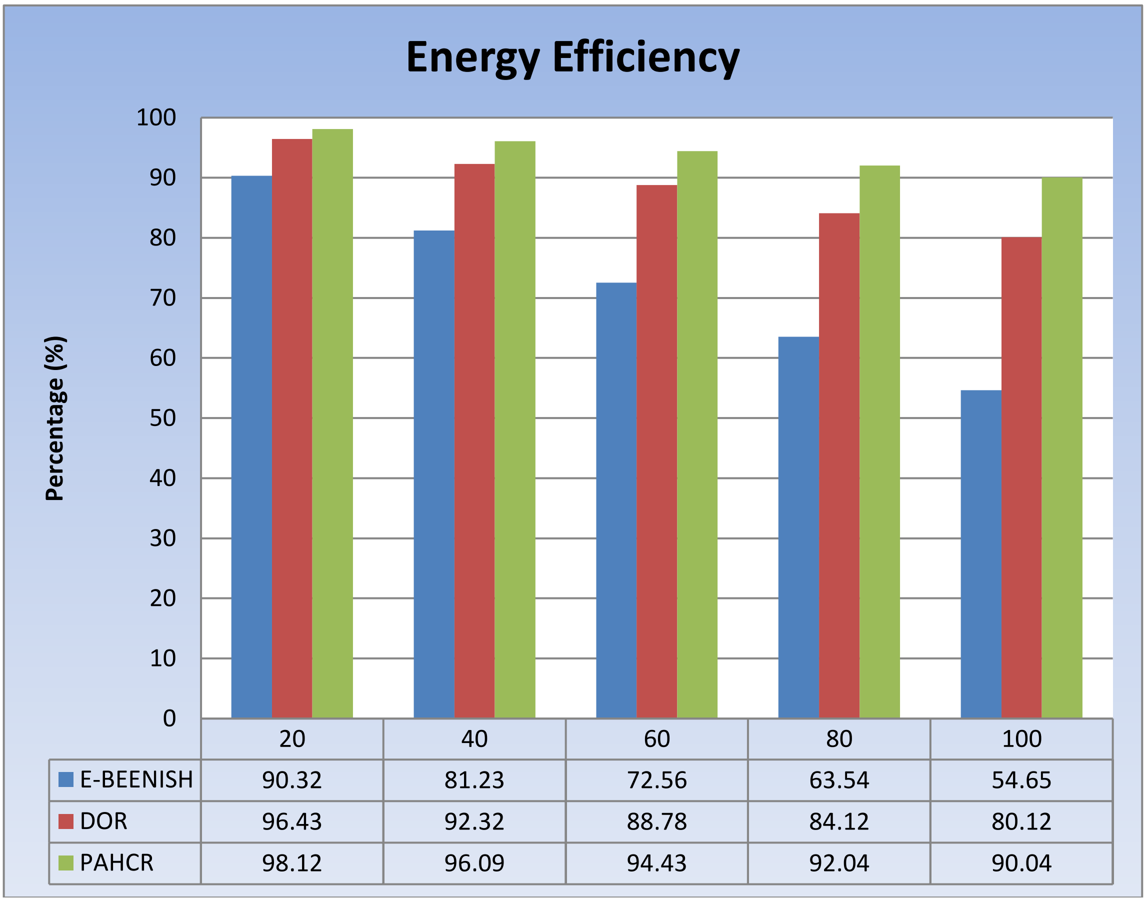

Figure 5. *Energy Efficiency*

4.2.Packet Delivery Ratio (PDR)

The PDR is calculated by dividing the quantity of properly delivered packets by the total quantity of packets transmitted from the origin. This indicator shows how packets must be routed by a protocol. Thus, the higher transmitting frequency is indicative of a more efficient procedure. PDR results from E-BEENISH, DOR, and PAHCR were shown in Table 3 and Figure 6. The proposed PAHCR provides a higher PDR than E-BEENISH and DOR at the varying size of packets.

Table 3. *Packet Delivery Ratio*

Packet Size (Bytes)	E-BEENISH	DOR	PAHCR
20	92.34	97.23	98.42
40	88.32	96.12	97.31
60	84.12	95.34	96.54
80	80.35	94.32	95.46
100	76.23	93.12	94.35

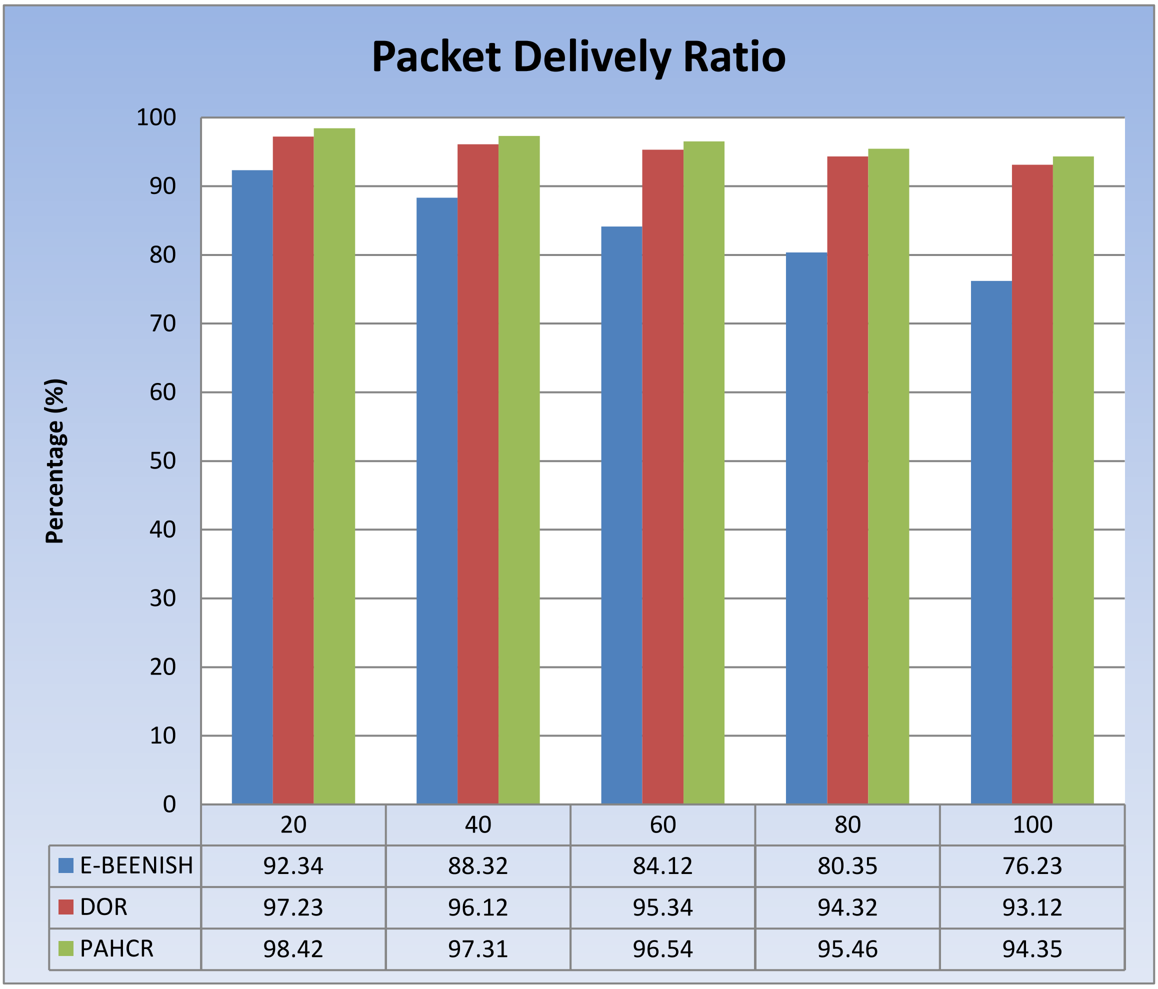

Figure 6. *Packet Delivery Ratio*

4.3.Throughput

Considerable attention should be paid to throughput as a measure of energy-efficiency. The throughput is a measurement of how many bits of information can be sent in a given amount of time. It is because of this feature that we can quantify the data throughput. The efficiency could be enhanced and packet drop decreased by rotating the CH by the threshold settings at SNs. Throughputs for E-BEENISH, DOR, and PAHCR at a multitude of bit rates are shown in Table 4 and Figure 7. In contrast to E-BEENISH and DOR, the proposed PAHCR always achieves a higher system throughput.

Table 4. *Throughput*

Transfer Rate (Kbps)	E-BEENISH	DOR	PAHCR
100	90.32	97.12	98.34
200	85.12	95.53	97.61
300	80.12	93.12	96.23
400	75.12	91.23	95.39
500	70.34	89.12	94.23

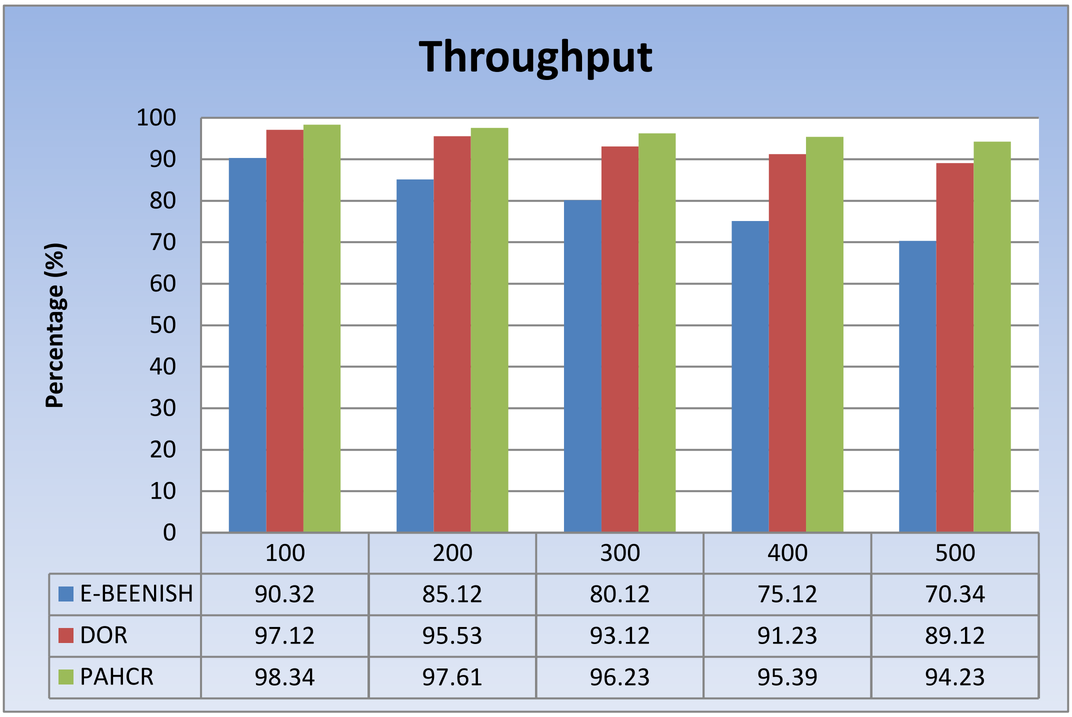

Figure 7. *Throughput*

4.4.Routing Overhead

As the number of SNs increases, more of them will want to participate in the transmission of the packets. As a result, there is a rise in communication overhead. Either the SN speed was increased or the latency affects a route from origin to the destination. Repeatedly, in an attempt to deal with the routing overhead, route creation or exploring should be initiated. To maintain the region dimension, choose the border SNs, and adjust the behavior, the protocol requires a vast number of packet commands. As the number of SNs grows, so does the routing complexity. Routing Overhead performance for E-BEENISH, DOR, and PAHCR are shown in Table 5 and Figure 8. Comparing the proposed PAHCR to the E-BEENISH and DOR protocols for varying numbers of nodes reveals that the PAHCR has a much lower overhead for routing.

Table 5. *Routing Overhead*

Number of Nodes	E-BEENISH	DOR	PAHCR
200	20.42	5.12	3.07
400	32.42	8.34	5.12
600	48.21	14.21	7.11
800	68.22	23.12	9.07
1000	91.21	32.56	11.23

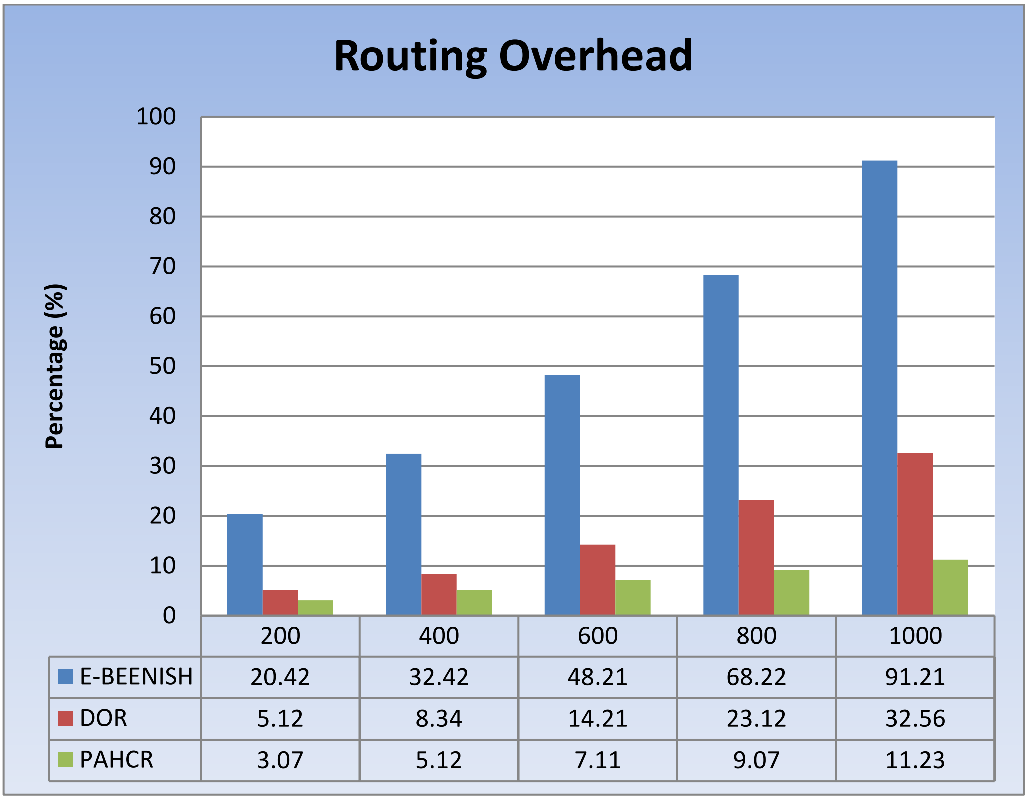

Figure 8. *Routing Overhead*

5. Conclusion

Due to the primary reason that an SN is an autonomous, power-starved device, developing WSNs with efficient routing methods is relatively hard. In SNs, the data transmitter and receiver serve as the principal energy sinks. Therefore, energy-efficiency and the potential for a prolonged WSN lifespan must be taken into account throughout the routing protocol's design. The ability to effectively transmit data in WSN, the PAHCR protocol has been proposed. Energy usage increases with each iteration of the CH picking and re-routing procedure here the PAHCR helps to alleviate this effect. In this method, each cluster inside a WSN is given a "Unique Identifier", which is then utilized as the transmission of data's "next hop". Instead of being chosen at random, CHs have been picked based on their RE. When a new CH is chosen, they take over the CI from the outgoing CH and hand it off to the incoming CH in the subsequent stage. This method decreases the WSN's energy requirements and extends its service life by performing the cluster creation and routing stages simultaneously, right after the network is set up. More research into improving energy savings and maintaining the system's targeted effectiveness in the context of other significant metrics is necessary for the future.

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