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RESEARCH ARTICLE

ICIC: A Dual Mode Intra-Cluster and Inter-Cluster Energy Minimization Approach for Multihop WSN

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ABSTRACT Energy minimization is one of the paramount issues in designing of the wireless sensor network and becomes more complex for multi-hop transmission. Furthermore, selection of multi hop route for the packets transmission is also a tedious task. In this paper, we propose an intra-cluster and inter-cluster (ICIC) energy minimization strategy for multihop wireless sensor network (WSN). In the proposed strategy, in intra cluster communication, a dynamic duty cycle allocation based on the cluster head (CH) node distance from the child nodes for the energy minimization is presented. In the inter cluster communication, minimum energy consumption route is chosen for the transmission of packets to base station (BS). The proposed strategy is compared with four state of the art techniques, i.e., HEEMP, LEACH, MLEACH, and SEP protocols of clustering. The evaluation of the proposed and existing strategies is done in two different scenarios i.e., number of round and number of nodes. Results of the simulation show that the proposed strategy transmits more packets and has lower number of dead nodes than other strategies. Furthermore, proposed strategy utilizes more network energy and more relaying energy.

INDEX TERMS LEACH, sensor node, WSN, network energy, cluster head, routing.

I. INTRODUCTION

In the present day, wireless sensor network (WSN) is used as a front end communication system such as in home automation, environment monitoring, industry, and in IoT, etc. It is an emerging potential technology for real time applications due to its low cost, small size, and ease of deployment [1], [2]. The WSN design depends upon the different scenarios of its application. In home automation and industry applications, where energy in not a constraint, packets delivery is the prime concern of network designing. Meanwhile, in hazardous environment where the battery is neither recharged nor replaced such as in mining, prolonging network life time is the prime factor for network designing. Furthermore, size of the deployed area also plays a crucial role in WSN designing. For small area, sensor node directly transmits packets to the sink node or base station, while in a large area, the packets are transmitted through multiple intermediate nodes to the sink node. In large area WSN designing, there are three major challenges: sub division of area, efficient routing, and intermediate nodes energy. In the sub division of area, the whole region is splitted into small sub regions which are known as clusters. In these clusters, one node is chosen as cluster head (CH) for receiving the data from the remaining sensor nodes of that cluster, and forwards it to the next node or sink node. In the WSN, many protocols for formation of clustering is proposed previously such as LEACH, MLEACH, SEP [3], [4], [5], [6]. In these protocols, prolonging network life time and efficient energy utilization is achieved by selection of CH node. In routing, two types of routing strategies are used [7]: flat routing and hierarchical routing. In flat routing, the route between sensor and sink node is searched; while in hierarchical routing, the

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sensor node transmits data to CH, and CH forwards it to the next CH node. A route is considered available only when intermediate nodes have enough energy for packets reception and subsequent transmission to the next node. This process is known as relaying and the intermediate nodes work as relay nodes for the multi-hop communication. If these nodes do not have enough energy for relaying, then transmission stops. Nodes which are near to the sink node or base station are frequently used for relaying purpose and this results in early draining of energy. Consequently, these nodes become dead, and a region of these dead nodes is created near the sink node, which is known as the warm hole region [8]. Therefore, selection of optimized route becomes a prime parameter for WSN design.

In WSN, a sensor node consists of a sensor, radio transmitter, receiver, processing unit, and battery. On the basis of these sensor node units, energy consuming components are as follows: sensing of data, data processing and, reception and transmission of signal from the node. Energy which is needed for sensing the physical quantity, like temperature, gas, humidity etc., is known as the sensing energy. Energy consumption in sensing is comparatively lower than the other energy consumption unit. Sensing data (i.e. any physical quantity like temperature, gas, humidity, etc.) is processed by the CPU which converts it into the form of packets and sends it to the transmitting unit of the node. The CPU also processes the data which is received from other nodes and this received data either augmented or forwarded to the next node. The major part of the energy of node is utilized by the reception and transmission units. In the radio model of energy consumption [9], transmitting distance plays a vital role in energy consumption. When the distance increases from the threshold limit, the energy consumption drastically increases [10]. Therefore, in order to save energy during packet transmission, data augmentation or minimum distance protocols have been proposed in WSN design.

In this paper, the problem of energy consumption in multi-hop wireless sensor network is addressed. In multi-hop communication, other issues such as routing, relaying node, and warm hole problem are also considered at the time of WSN design. In the proposed strategy, a joint mechanism based on intra and inter cluster communication is proposed. In intra-cluster communication, a node which has enough energy for data gathering and transmitting it to the next node of the route is chosen as cluster head (CH) node. All the other sensor nodes transmit data to the selected CH node. In the proposed strategy, energy consumption is minimized by controlling the transmission time of the sensor nodes. Since, energy consumption is directly proportional to the distance of the child node, more transmission time is given to the nearer nodes which results in higher number of packets delivery at the same residual energy when compared to the farther nodes. The time when the node transmits the signal is known as active time, while the time when node is not transmitting the signal is known as passive time. The ratio of the active to passive time is known as duty cycle, and the process of assignment of different duty cycles to the nodes is known as dynamic duty cycling. Various MAC protocols are developed to manage the on/off time of transmission, The medium access control (MAC) layer, which is part of the data link layer, is one of the most important factors in the overall energy efficiency of a communication protocol. The MAC layer is responsible for establishing a reliable and efficient communication link between WSN nodes as well as wasting energy. Following WSN MAC protocol features are considered into account: energy efficiency, reliability, low access delay, and high throughput [9]. For wireless sensor networks, TDMA is probably the best option for an energy-efficient multiple access protocol. In multi-hop networks, TDMA transmissions usually identify the shortest length conflict-free slot assignment in which each link or node is activated at least once. In the inter cluster communication process, each CH node transmits data to the next CH node of the route, and this process repeats until all the packets reached to the BS. For inter-cluster communication, among all the available route, the route which require least energy for the data transmission is chosen. The major contributions of this paper is as follows:

1) To the best of our knowledge, a first time dynamic duty cycling for multi-hop WSN is proposed.
2) Energy consumption is minimized by intra cluster as well as inter cluster communication of the node.
3) Duty cycle assignment is automatically adjusted for the different node distance.

The rest of the paper is laid out as follows: Section II presents the related work based on the multi-hop wireless communication; background and motivation, energy utilization radio model, and network designing constrains are presented in Section III, proposed and existing strategies are given in Section IV, simulation results and conclusion are presented in Section V and Section VI, respectively.

II. LITERATURE REVIEW

In this section, related work based on the multi-hop communication in WSN design for various problems is presented. In the WSN, LEACH is one of the most often used clustering techniques. The key notation is that every node in the network should be able to become a CH at least once every N/K rounds, where N represents the number of nodes in the network and K is the desired number of clusters [11]. In [12], IE2-LEACH an improved version of conventional LEACH is proposed wherein the cost of the signal transmission to BS is considered for the selection of CH node. A dynamic multi-hop energy efficient routing protocol (DMEERP) is proposed in [13]. In DMEERP provision of two cluster head nodes, i.e., super CH and CH, is given and also the load balancing is used to achieve more packets delivery and reliability. On the basis of correlation value of the node, a correlation model for improving the network lifetime is given in [14]. By taking the leverages of flat and hierarchical routing, a hybrid multipath energy efficient routing is proposed in [15]. A genetic algorithm for increasing the network life time, based on the optimal data routing for the mobile sink node, is proposed in [16].

For increasing the reliability in under water communication, a two hop acknowledgement-based strategy is proposed in [17]. A strategy based on the minimum connected dominant set and bi-Partite graph algorithm for increasing the energy efficiency and network life time for multi-hop communication is proposed in [18]. Using unequal clustering, energy consumption minimization and increasing network lifetime, a fuzzy based protocol is proposed in [19]. In [20], a two tier, i.e. selection of CH and optimal route using fuzzy based protocol for minimum energy consumption is presented. Data fusion with the ant colony optimization strategy which considers reliability, load balancing and node energy is given in [21]. Routing based on the highest energy on intermediate nodes is presented in [22] and also overhead control mechanism for higher packets delivery is given. A minimum energy consumption route searching K means algorithm based on node energy, distance from BS, and number of route is presented in [23].

For the problem of multiple sink nodes, an ant colony optimization strategy to increase the network life time and minimization of data is proposed in [24]. Using glowworm swarm and fruitfly optimization for selection of optimal CH, a higher energy efficiency and network lifetime is achieved in [25]. In [26], for selection of CH node butterfly optimization and for the optimal route selection, ant colony optimization is used. An ant colony optimization based on energy efficiency and balancing of distance for increasing the network lifetime in given in [27]. A zonal clustering algorithm wherein two separate CH nodes for intra and inter cluster communication is proposed in [28]. The CH for intra-cluster communication is known as primary CH, whereas inter cluster communication node is known as backup CH.

In [29], multi variable weight route selection the algorithm based on the residual energy and distance of the node for high density seismic array is presented. Using spanning tree, a strategy for energy consumption distribution over the CHs by multipath data routing is proposed in [30]. Yuchao *et al.* present a genetic-based approach that uses unsupervised learning in probability to discover an optimal chromosome for constructing a close-to-optimal network topology [31]. Using the approach of multi-objective optimization (MOO), Fei *et al.* gave a tutorial and a summary of recent research and development initiatives addressing this issue [32]. Yuchao *et al.* proposed a dynamic hierarchical protocol (DHCO) based on combinatorial optimization to balance sensor node energy consumption and improve WSN lifetime. Instead of selecting the cluster head or the next hop node, the DHCO algorithm finds the best path for each sensor node by creating a feasible routing set [33]. In [34] balancing and energy efficient multi-hop (BEEMH) strategy, which is based on the relaying nodes maximum residual energy, for enhancing network lifetime is proposed. A tradeoff between energy efficiency and delay is presented in delay constraint energy multi-hop strategy (DCEM) [35]. An energy minimization approach based on the excess use of CHs is proposed in [36]. Energy harvesting wireless sensor network design based on the unified approach for the quality of monitoring is given in [37]. Using cooperative communication, a wireless power transfer strategy and transfer of the signal along with power signal is presented in [38] and [39], respectively.

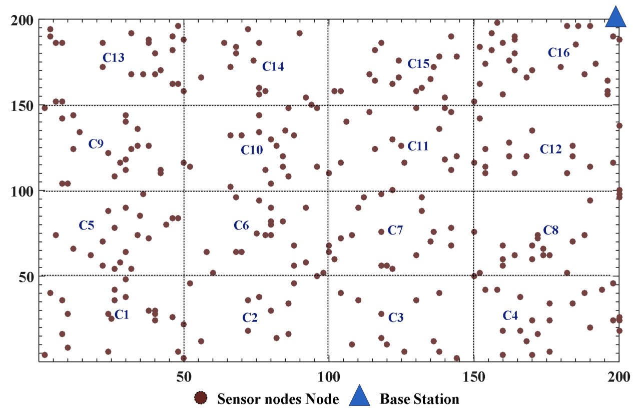

FIGURE 1. (200 × 200) m^2 area is divided into 16 clusters and 300 sensors are deployed over the entire region.

For search optimal route and CH, in [40], an exponential ant colony optimization for routing and fractional artificial bee colony optimization for CH selection is given. A cat salp optimization for addressing the network security is given in [41]. A hybrid algorithm based on minimum spanning tree and minimum distance tree selection for intra and inter cluster communication is given in [42]. With the use of data aggregation and changing the transmitting route to an alternate way, the network lifetime is increased in [43]. By computing the gradient value of the sensor node, a gradient based clustering and minimum hop route search algorithm is proposed in [44]. An overlapping clustering algorithm for equal clustering and load balancing is given in [45]. Summary of protocols with advantages and limitations are given in Table 1.

III. BACKGROUND AND MOTIVATIONS

The sensors are randomly deployed over the network field. All the deployed nodes have equal energy and they cannot be recharged. The network field is divided into different clusters and each cluster is of equal size. The nodes in the cluster send data to their cluster head (CH), and the CH forwards all the data along with its own data to the nearby CH. This process is repeated until all the data reaches the base station (BS). The CH of each cluster must ensure optimal energy consumption route before sending data to the BS.

Let us consider the network field of (200 × 200) m^2 and the total area is divided 16 clusters as shown in Figure 1. The BS is located at the position of (200, 200). The field area is hostile therefore sensor nodes are randomly deployed over the entire field. Each sensor node (i.e. child node) gathers information and sends it to the CH node of the current round. The allocation time to the child node for transmission depends on the protocols used for data sending. After reception of data

TABLE 1. Summary of literature review.

Author	Protocol	Description	Advantages	Limitations
Heinzelman, et al. [11]	LEACH: The key notion is that every node in the network should be able to become a CH at least once every N/K rounds, where N represents the number of nodes in the network and K is the desired number of clusters	It divides the sensor nodes into a number of tiny clusters. Each round of LEACH is divided into two parts: (1) The clusters are constructed and the cluster-heads of each cluster are elected during the setup phase. (2) The detected data is transferred to the base station through CHs during the steady state period. Randomly	(I) Reduce the number of control messages sent. (II) Local compression using a low-complexity technique to reduce global data communication.	(i)Uniform distribution of Chs is not offered (ii)randomly CH election (iii)Send data using 1-Hop concept
Saleh et al. [12]	IE2-LEACH: It is an improved version of conventional LEACH is proposed wherein the cost of the signal transmission to BS is considered for the selection of CH node	IE2-LEACH considers the geographic location of each header as a parameter in order to detect the vices of CHs.	Network life time is considerabely increased	The average energy use.
Nivedhitha et al. [13]	DMEERP: To balance the path reliability ratio and energy consumption, the dynamic Multi-hop Energy Efficient Routing Protocol (DMEERP) is developed.	The clustering was done using a network model. This model explains how CH and SCH work together to improve network performance. From SCH to CH and CMs, multi-hop routes are built.	Suitable for Multi hope communication	Not suitable for single hope or direct communication model.
Sajwan et al. [15]	This algorithm maximises energy economy by combining flat and hierarchical routing schemes.	Nodes in clusters use multi-hop routing to communicate with the cluster head. The data is aggregated by CH and sent to the BS along a pre-determined path. Intra-cluster communication can be philanthropic (choosing the node with the highest residual energy) or selfish (choosing the node with the lowest residual energy) (where the nearest node is chosen as the next hop).	Suitable for Multi hope communication only	Not suitable for single path communication.
shokair et al. [34]	BEEMH: The BEEMH (Balanced and Energy Efficient MH) algorithm is based on the Dijkstra algorithm. It pays close attention to the remaining energy of nodes; as a result, higher-energy nodes are chosen only to serve as relays.	To model the weight of linkages between nodes, the total energy usage at both TX and RX was combined. Finally, the Dijkstra algorithm is used to find the least expensive path quickly.	Mostly suitable for multipath routing.	Network energy consumption is unstable
Huynh et al. [35]	Agrange relaxation method and aggregate cost function are used to decrease delay and energy usage.	The proposed method established a decent compromise between energy usage and delay time.	Significant delay is reduced	Average energy savings is average.
Vinitha et al. [41]	C-SSSA: The suggested Taylor C-SSA is used to pick the best hops.	The suggested Taylor C-SSA is used to pick the best hops. Furthermore, security conscious multi-hop routing is implemented using a trust model that includes indirect trust, integrity factor, direct trust, and data forwarding rate, among other things.	Enhanced energy efficiency less dehay and high throughput achieved	Less secure data transmission.
Juan et al. [46]	A routing algorithm based on saving of minimum residual energy is given.	For data relay, the emphasis is on low energy usage and long network life.	(i)Power consumption is kept to a bare minimum. (ii)Network performance has improved. (iii)Protect low-residual-energy nodes.	There is no mention of the sensor's sleep mode.
Mianxiong et al. [47]	Using reliability and Multi-way Encounter Routing, energy consumption minimization algorithm is proposed.	In this method majority of nodes chosen at the hot spot area whereas minimum CH nodes are chosen at nearby BS area.	(i)Reliability of the meeting. (ii)Energy consumption is reduced. (iii)An increase in network performance.	Energy savings are average.
Shaojie et al. [48]	In real-time IoT applications, an energy-efficient distributed routing technique is proposed.	A mathematical optimization based on cooperative communication is proposed.	(i)Improved network, throughput, and so on. (ii)Changes to network attributes and channel circumstances are permitted.	When sending packets, the void region problem is ignored.
Satish et al. [49]	LLN to LBR route search method based on cognitive routing is introduced.	Network router recives data from leaf nodes.	(i)Develop a more energy-efficient channel path. (ii)Improve network performance and end-to-end delay.	Lower energy consumption and throughput are possible.
Manu et al. [50]	Developed a WSN routing approach for handling high traffic for IoT application networks.	Based on the link quality and noise effect, the protocol is meant to identify the optimal next node. This strategy is ideal for networks with a high volume of traffic.	(i)Improve network resiliency. (ii)Manage a high volume of traffic. (iii)Decongest the area. (iv)An increase in throughput, end-to-end latency, and residual energy.	Dynamic traffic schemes are less compatible.
Vishal et al. [51]	For WSN, ACO-based energy balance method is proposed.	Introduce an ACO-based technique that considers three phases while determining the most effective route: cluster formation, data transfer, and multipath generation.	(i) Longevity of the network. (ii) A longer period of stability. (iii) Energy consumption is reduced.	The usage of energy is considered on a small level.
Haibo et al. [52]	Introduced an enhanced LEACH algorithm and the clustering principle of the Voronoi diagram.	After introducing the Voronoi diagram, the optimal cluster head is computed for energy usage, and then ACO is added to improve the routing protocol.	(i) Energy usage is reduced. (ii) Increased network longevity.	(i) There is a lower level of interoperability with intelligent protocols. (ii) There is a lower likelihood of successful implementation.
Rabiaa et al. [53]	To overcome the hotspot problem, implement a clustering technique.	Small size cluster near to BS and relatively larger size cluster for farther nodes is made.	(i) Maintain node energy levels in balance. (ii) Increases network longevity.	Least compatible with sensor nodes that are heterogeneous.
Ayesha et al. [54]	SAVEER: It is a routing scheme that focuses on energy conservation.	A greedy algorithm based on minimization of void problem given.	(i) The void problem has been reduced. (ii) A more efficient use of energy. (iii) A longer network lifespan.	In a multi-hop setting, it is less suited.
N C Sachithanantham,& V Jaiganesh. [55]	To increase QoS in WSN, an effective mechanism for forwarding data packets was proposed.	This method provides a methodology that employs the flooding notion to transfer data packets in a dynamic manner while taking the most efficient path. Furthermore, many machine learning algorithms are employed to forward data packets.	(i) A reduction in energy use. (ii) Extend the life of the network. (iii) Shorten the period between delays.	The sensor nodes in the network have a smaller coverage area.
Bilal et al. [56]	In WSN-IoT applications, an optimal path finding based on clustering is proposed.	Based on weighted vertex leaves problem minimum energy route is searched for mobile sink node.	(i) Improved WSN network performance. (ii) Fixed the energy hole issue.	The average energy use.

from the child nodes, the CH either forwards it to the next CH or directly transmits it to the BS, based on the minimum energy consumption route. In this scenario, the motivations for the design of wireless sensor network are as follows: (1) To search optimal energy consumption route for packet transmission in multi hope WSN, (2) To Increase the packet delivery to BS, (3) Increasing the network lifetime by reducing the energy consumption of the node, (4) To utilize the

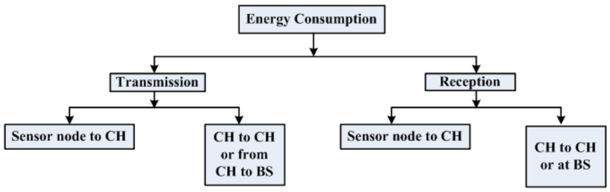

FIGURE 2. Energy consumption in multihop sensor network.

TABLE 2. Notations.

NC	Number of cluster
SN	Sensor Node
c	a cluster
NSN_c	Number of sensor nodes in 'c^{th}' cluster
CH	Cluster head node
PT_{sn}/PT_{CH}	Number of packets transmitted by sensor node 'sn'/cluster head node 'CH'
$DutyCycle_{sn}$	Duty cycle assigned to sensor node 'sn'
$PRCH_c$	Packets received by 'c^{th}' cluster head
E^{res}_{sn}	The residual energy of sensor node 'sn'
$E^{res}_{CH,C}$	The residual energy of 'c^{th}' cluster head node
K	Total number of routes reserved for inter cluster communication
TE_{sn}/RE_{sn}	Energy consumption for transmission/reception of sensor node 'sn'
$TE_{CH,C}/RE_{CH,C}$	Energy consumption for transmission/reception 'c^{th}' cluster head node
E_k	Energy consumption for data transmission on the 'k^{th}' route
E_{min}	Minimum energy consumption route
E^{r}_{min}	Minimum energy consumed by a route 'r'
CH^{r}_{min}	Set of all the cluster head belongs to minimum energy consumption route

available network capacity maximum and, (5) To minimize the effect of warm hole problem for multi hope WSN.

A. MODEL OF RADIO AND ENERGY CONSUMPTION

A sensor node consumes energy either during reception or during the transmission of data. Data is received either from the child nodes or other nearby CH nodes. Similarly, data is transmitted either from the sensor (child) node to CH, or from CH to the next CH. Figure 2 shows the classification of data transmission and reception energy consumption.

Notations used in this paper is given in Table 2

Let us consider S_{NP} is the total number of packets received by CH node from child nodes and each packet has B bits. In this paper 4000 bits per packet is considered. The energy consumed by CH for the reception of the signal is given as in Equation 1:

$$RE_{sensorNode} = S_E \times S_{NP} \times B \quad (1)$$

where S_E is the sensing energy needed to CH node.
Let the number of packets transmitted by near CH is CH_{NP}. The energy for the reception of CH_{NP} packets is given in Equation 2:

$$RE_{CHNode} = S_E \times CH_{NP} \times B \quad (2)$$

Hence, the total energy consumption in signal reception by adding Equation (1) and (2) is given in Equation (3) as:

$$TRE_{CHNode} = RE_{sensorNode} + RE_{CHNode}$$
$$= S_E \times B(S_{NP} + CH_{NP}) \quad (3)$$

The energy requirement for transmission of the packets to CH at distance D is given as sown in Equation 4 [10]:

$$TE_{sensorNode} = \begin{cases} B \times S_{NP}(E_{elec} + \epsilon_{fs} \times D^2) & D \leq D_{th} \\ B \times S_{NP}(E_{elec} + \epsilon_{mp} \times D^4) & D \geq D_{th} \end{cases} \quad (4)$$

Similarly, energy consumption for transmission of CH to next CH is given as in Equation 5:

$$TE_{CHNode} = \begin{cases} B \times CH_{NP}(E_{elec} + \epsilon_{fs} \times D^2) & D \leq D_{th} \\ B \times CH_{NP}(E_{elec} + \epsilon_{mp} \times D^4) & D \geq D_{th} \end{cases} \quad (5)$$

Hence, total energy consumption for transmission of the packets is computed by adding Equation 4 and 5 is given as:

$$TTE_{CHNode} = TE_{sensorNode} + TE_{CHNode} \quad (6)$$

In Equation 4 and 5, E_{elec} is energy consumed in electronics for processing a bit, ϵ_{fs} is free space amplification coefficient, ϵ_{mp} is multi-path amplification coefficient D_{th} is the threshold distance and it is given as $D_{th} = \sqrt{\frac{\epsilon_{fs}}{\epsilon_{mp}}}$

IV. EXISTING AND PROPOSED STRATEGIES

The four existing strategies, HEEMP, LEACH, MLEACH, SEP, and one proposed ICIC strategy are presented in this section.

A. HYBRID ENERGY-EFFICIENT MULTI-PATH ROUTING PROTOCOL (HEEMP)

In this strategy, among all the available routes, the route which needs the lowest energy for data transmission is selected for the transmission [15].

B. LOW-ENERGY ADAPTIVE CLUSTERING HIERARCHY (LEACH)

In this strategy, a node is randomly selected as cluster head (CH) and the other sensor nodes transmit data to this CH node. The CH node aggregates all the data and forwards it to the next CH node in the transmission route [15].

C. MULTI-HOP LEACH

In the MLEACH strategy, any one node is selected as the CH node and that node act as CH until it is unable to forward data to the next CH [5].

D. STABLE ELECTION PROTOCOL (SEP)

In SEP, nodes are segregated into primary and secondary nodes. The primary nodes can become CH node and secondary nodes always work as as child nodes. In this paper, SEP is evaluated with three different primary and secondary node ratios: 30:70, 50:50, and 70:30 respectively [6].

E. PROPOSED (DUAL MODE INTRA-CLUSTER AND INTER-CLUSTER (ICIC) ENERGY MINIMIZATION ALGORITHM)

The proposed ICIC strategy minimizes the energy in two modes: intra cluster mode and inter cluster mode. In intra

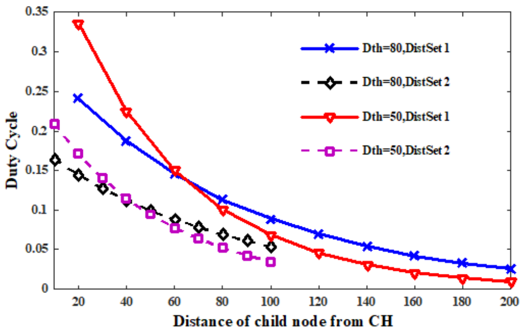

FIGURE 3. Variation in duty cycle assignment when the distance of child node from CH increases.

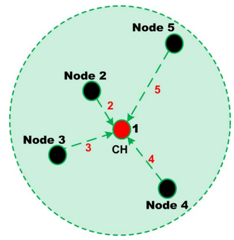

FIGURE 4. Five node cluster where four child nodes and one CH with their distance is shown.

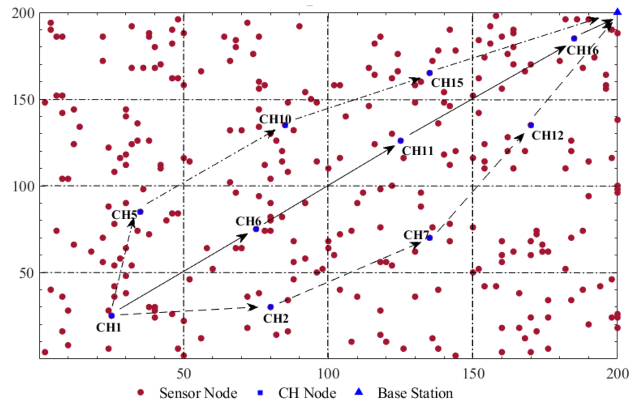

FIGURE 5. Different signal transmission routes from CH1 to BS.

cluster, dynamic duty cycle is assigned to child nodes in order to minimize the energy consumption. Allocation of duty cycle is based on the distance of the child node from the CH node. In inter cluster mode, least energy consumption multihop route is chosen for the data transmission. The detailed explanation with the example is as follows:

1) INTRA-CLUSTER ENERGY MINIMIZATION

In intra cluster mode, one of the node is selected as CH node and remaining sensor nodes become child node. Each child node has different duty cycle is assigned. The duty cycle assignment to child node depends on the distance from the CH node. Let us consider N_c nodes are available in a cluster. The function of duty cycle assignment is as follow:

$$DutyCycle_{CH,SN} = \frac{e^{\frac{-D_{CH,SN}}{d_{th}}}}{\sum_{n=1}^{N_C-1} e^{\frac{-D_{CH,n}}{d_{th}}}} \quad (7)$$

In Equation 7, the CH and SN represent cluster head and sensor node, respectively. $D_{CH,SN}$ is the distance between the child node SN and CH, and D_{th} is the threshold distance. In Figure 3 distribution of duty cycle for 10 child nodes is shown. Based on Figure 3, two data sets of distance (child node to CH node) is considered, i.e., DistSet1 and DistSet2. The DistSet1 = [20, 40, 60,− − −−,200] and DistSet2 = [10, 20, 30,− − −−,100]. Also, two threshold values are considered i.e., $D_{th} = 80$ and $D_{th} = 50$. Figure 3 shows the following information of duty cycle assignment to child nodes:

1) Child nodes nearer to the CH node, will get the highest share of duty cycle.
2) At the same distance, a child node of the larger size cluster which is nearer to CH, assigned more duty cycle.
3) Threshold distance also controls the duty cycle assignment. As the D_{th} increases, the allocation of the duty cycle to child nodes becomes homogeneous.

Let us consider Figure 4, where five nodes of a cluster are given. Node 1 is selected as CH node. The distance set from child nodes 2, 3, 4, 5 is DistSet = [1, 2, 3, 4] and the threshold distance $D_{th} = 2.5$ are considered. The duty cycle assigned to Node 2 to Node 5 using Equation 7 is 0.4, 0.276, 0.185, and 0.123, respectively.

2) INTER-CLUSTER

In the inter-cluster communication, energy consumption is minimized by transmitting data through a minimum energy consuming route. In inter-cluster communication, CH computes their energy needed for the transmission of packets via different routes. Among those routes, the route which needed less energy for transmitting packets is chosen for the inter-cluster communication.

Consider the WSN as shown in Figure 5, where the CH1 node wishes to transfer data to the BS. CH1 node sends beacon messages to all the routes leading to the BS. In Figure 5, three routes between CH1 to BS is given and all three routes have the same number of hops. Among all the three routes, the route which require the lowest energy for delivering packets to the BS is chosen. Hence in the proposed strategy, in inter-cluster communication, energy consumption is minimized by selecting the lowest energy consumption route.

The Flow chart of the proposed algorithm is shown in Figure 6 and Algorithm 1 represents the working of proposed ICIC strategy. There are two phases of the algorithm: intra-cluster and inter-cluster. In intra-cluster, energy is minimized by optimum duty cycle allocation to the child nodes while minimum energy consumption route is given priority for inter-cluster communication. Step 1 is for considering all the clusters in the WSN and complexity is NC. The number of packets received by the CH node is initialised in Step 2.

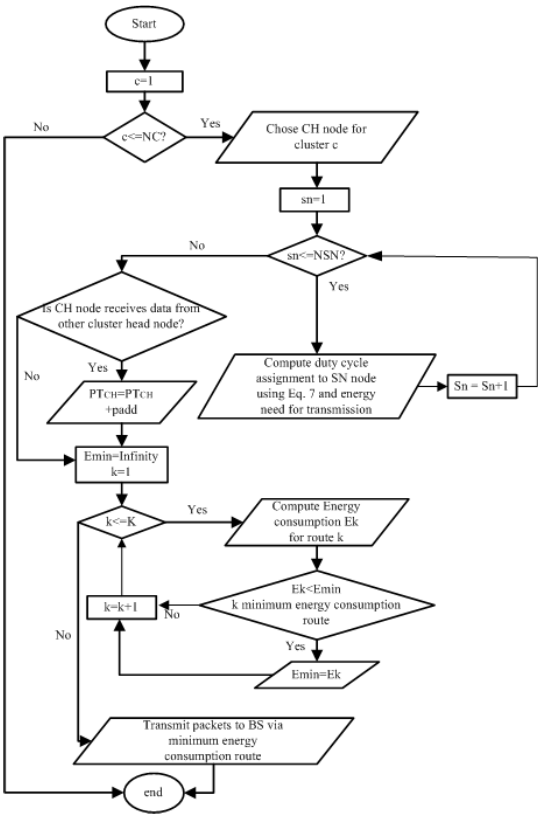

FIGURE 6. Flowchart of packet transmission from cluster to BS in ICIC strategy.

In Step 3, the cluster head node is chosen using a random function. Step 4 and 5 for considering the child nodes of the cluster. Duty cycle assignment to child node using Equation 7 and computation of the number of packets transmitted to CH is given in Step 6. Step 7 reduces the amount of energy required for signal transmission and reception in child and cluster head nodes. And, also computes the total number of packets received by child nodes. Step 8 and 9 are for the closing of the loop. The computation complexity of steps 4 to 9 is $O(NSN_c)$. In Step 10, packets generated by CH are added along with the received packets of child node.

Step 11 initializes the energy consumption for transmission to BS. Step 12 to 17 are for finding the minimum energy consumption route which has computation complexity O(K). Packets transmission to BS is given in Step 18. Step 19 to 21 used for computation of residual energy of CH nodes after transmission and reception of packets. And, computation complexity is the total number of clusters i.e. NC. Step 22 is the end of for loop of Step 1.

The for loops of Step 4,12 and 19 are the inner nested loop of step 1. Hence the final total number of operation is $O(NC(NSN_c + K + NC))$

3) WORKING OF PROPOSED ICIC STRATEGY

Let us consider the network topology of six sensor nodes and a base station (BS) as shown in Figure 7. The location of deployed sensor nodes and BS, and distance between

Algorithm -1 Proposed ICIC Strategy

Phase I: Intra-cluster, i.e. data transmission from child node to CH node in each cluster

1: **for** c = 1 to NC **do**
2: $PRCH_c \leftarrow 0$ //packets received by CH node
3: Chose cluster head CH_c node using random function
4: **for** sn = 1 to NSN_c **do**
5: **if** $sn \neq CH_c$ **then**
6: Compute duty cycle assignment, i.e. $DutyCycle_{sn}$ using Equ.7 and number of packets transmitted PT_{sn} in given time.
7: $PRCH_c \leftarrow \mathrm{PRCH}_c + PT_{sn}$;
$E^{res}_{sn} \leftarrow E^{res}_{sn} - TE_{sn}$;
$E^{res}_{CH,C} \leftarrow E^{res}_{CH,C} - RE_{CH,C}$
8: **end if**
9: **end for**
10: $PRCH_c \leftarrow \mathrm{PRCH}_c + PT_{CH}$ // Add packets of cluster head node to the total number of packets

Phase II: Inter cluster communication, i.e. energy efficient route selection

11: $E_{min} \leftarrow \infty$ // Minimum energy for transmission
12: **for** k = 1 to K **do**
13: Compute the energy consumption of route (i.e. E_k) for transmitting $PRCH_c$ packets
14: **if** $(E_k < E_{min})$ **then**
15: $E_{min} \leftarrow E_k$; $E^r_{min} \leftarrow k$
16: **end if**
17: **end for**
18: Transmits packets to BS using minimum energy consumption route i.e. E^r_{min}
19: **for** $\forall CH \in CH^r_{min}$ **do**
20: $E^{res}_{CH,C} \leftarrow E^{res}_{CH,C} - RE_{CH,C}$;
$E^{res}_{CH,C} \leftarrow E^{res}_{CH,C} - TE_{CH,C}$;
21: **end for**
22: **end for**=0

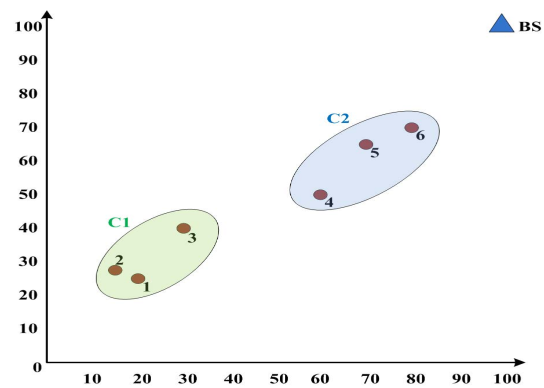

FIGURE 7. Location of nodes with respective clusters.

the nodes is given in Table 7 and Table 8 in Appendix, respectively. The sensor nodes are divided into two clusters: C1 and C2.

Cluster C1 consists three nodes, i.e., 1, 2, and 3, while Cluster C2 consists nodes 4, 5, 6. Nodes of cluster C1 are

TABLE 3. Simulation data of energy consumption (mJ) per round in each sensor node.

Round No	CH Node		Energy consumption in mJ for transmission of signal from child node to CH node						Energy consumption in mJ in CH node for signal reception from child node						Energy consumption for transmission of signal from CH to next CH node		Residual energy (in mJ) of sensor nodes after completion of round					
	C1	C2	C1			C2			C1			C2			CH1 to CH2	CH2 to BS	1	2	3	4	5	6
			1	2	3	4	5	6	1	2	3	4	5	6								
1	1	4	0	10.5	9.98	0	10.8	10.6	21.3	0	0	42.6	0	0	27.6	71.3	451.1	489.5	490.02	386.1	489.2	489.4
2	2	5	10.5	0	9.9	10.5	0	9.9	0	21.3	0	0	42.6	0	36.7	52.28	425.5	431.5	480.1	375.6	394.32	479.5
3	3	6	10.4	10.7	0	10.2	11	0	0	0	21.5	0	0	43.1	32.8	49.38	415.1	420.8	425.8	365.4	383.32	387.02
4	1	5	0	10.5	9.98	10.5	0	9.9	21.3	0	0	0	42.6	0	35.1	55.28	358.7	410.3	415.8	354.9	285.44	377.12
5	2	6	10.5	0	9.9	10.2	11	0	0	21.3	0	0	0	43.1	42.9	49.13	348.2	346.1	405.94	344.7	274.44	284.89
6	3	4	10.4	1.78	0	0	10.8	10.6	0	0	21.5	42.6	0	0	23.5	70.97	337.8	344.32	360.94	231.13	263.64	274.29
7	1	6	0	10.5	9.98	10.2	11	0	21.3	0	0	0	0	43.1	40.8	49.13	275.7	333.82	350.96	220.93	252.64	182.06
8	2	4	10.5	0	9.9	0	10.8	10.6	0	21.3	0	0	10.8	0	29.3	70.61	265.2	283.22	341.06	150.32	241.84	171.46
9	3	5	10.4	10.7	0	10.5	0	9.9	0	0	21.5	0	42.6	0	28.3	55.56	254.8	272.57	291.26	139.82	143.68	161.56

unable to transmit data directly to the BS therefore cluster head (CH) node of cluster C1 sends packets to the CH of cluster C2, and subsequently CH of cluster C2 transmits the received packets of CH1 along with the packets of child nodes of its own cluster i.e. C2 to the BS.

The working of proposed strategy round by round is given in Table 3. In the first column number of rounds is given. In Round 1, CH nodes of clusters 1 and 2 are Node 1 and Node 4, respectively, as mentioned in the Table 3. The other nodes of both the clusters works as the child nodes in the Round 1. In Cluster C1, Node 2 and 3 work as the child nodes and the assignment of duty cycle using Equation 7 to these child nodes are 0.53 and 0.47, respectively as mentioned in Table 9 in the Appendix. It is evident from the table that shorter distance nodes have assigned more duty cycle comparatively. The duty cycle assignment to child nodes in each round of both the clusters is given in Table 9. Based on the duty cycle assignment, transmission time is given to the child nodes. In this example, total transmission time in the round is 60 seconds considered and 910 ns is required for transmission of each packet of 4000 bits. The computation of the transmission of number of packets is given in the Table 10. The child nodes which are nearer to the CH nodes transmits more packets comparatively than the longer distance nodes. Transmission energy required for the transmission is computed using Equation 4 and 5, the transmission energy needed for child nodes are given in Table 3. In Table 3, the detailed energy consumption data of each sensor node for Round 1 to Round 9 is given. In the table, all the scenarios of CH combinations are considered.

CH nodes received the bits transmitted by child node as well as previous CH node. Here, CH1 receives packets from child nodes, while CH2 node receives packets from child nodes and from CH1 node also. Therefore, energy consumption for reception of the packets in CH2 is higher than the CH1. In Round 1, CH2 receives 97 packets from CH1, and the same 97 packets from Child nodes 5 and 6. Therefore, energy needed for reception of signal for CH2 is double than CH1 in Round 1. Furthermore, CH2 requires higher energy for transmission of packets from CH2 to BS.

In Table 3 the residual energy after completion of Round 1 is given. Sensor nodes 2, 3, 5, and 6 work as child nodes therefore they consumes energy for signal transmission to CH node only and their residual energy is computed by reducing the packet transmission energy than the previous energy, i.e., 500 mJ. On the other hand, CH nodes consumes energy for packets reception and in transmission of the same to the next CH node or to BS.

V. SIMULATION AND RESULTS ANALYSIS

For evaluation of the proposed and existing strategies, we developed a simulator in MATLAB software. In simulation, an area of 200 × 200 m^2 is considered as shown in Figure 1. The whole area is split into 16 clusters of 50 × 50 m^2. The location of the base station is set at (200, 200). The area is considered as hostile environment therefore the sensor nodes are randomly distributed over the entire region. Each sensor node has limited energy and it cannot be recharge once it becomes dead. A node is considered dead when its energy decreases below the minimum threshold energy required for signal processing. Here $E_{th} = 1mJ$ is considered for simulation. The presented results are the averaging of 100 times simulation of each strategy. The other parameters which are considered for the simulation are given in Table 4. Meanwhile designing of the simulator the following assumption and constraints are considered:

1) Radio model for energy consumption in sensor nodes are considered.
2) Once the sensor nodes deployed, their location cannot be changed.
3) Energy of the sensor nodes is fixed and, neither recharged nor replaced.
4) For multihop routing, K shortest path between the CH node and BS is used.
5) Route is selected only when intermediate nodes of routes have enough energy for transmission and reception.

The performance evaluations on different metrics of the proposed and existing strategies are as follows:

A. PACKETS DELIVERY TO THE BASE STATION

Packets delivery with respect to number of rounds is given in Figure 8. As the number of rounds increases; the amount of packets delivered also increases. Here, round means collections of packets from child nodes of the cluster and transmission of the received packets to the BS. In the

TABLE 4. Parameters used in simulation.

Parameters	Values
Number of sensor nodes (n)	200 to 400
Area of the network	$200 \times 200\ m^2$
Initial energy of nodes (E_0)	5mJ
Threshold energy (E_{th})	0.1mJ
Position of base station	200, 200
Total number of cluster	16
Area of each cluster	$50 \times 50\ m^2$
Frame size	4000 bits
Each round time	60 second
MAC protocol	TDMA
Amplification coefficient of free space signal (ϵ_{fs})	10pJ/bit/m^2
Multipath fading signal amplification coefficient (ϵ_{mp})	0.0013pJ/bit/m^4
Energy consumed by in electronic circuit (E_{elec})	50nJ/bit
Energy consumed in data aggregation (CH_{DA})	5nJ/bit

simulation, we considered each round is equivalent to 60 second. In the conventional strategies, 60 second time is equally divided among the child nodes, while in proposed ICIC transmission time assigned to the child nodes on the basis of their distance so that more packets can be transmitted to the BS. When network nodes have enough energy, then they transmits packets to the BS; therefore, packets delivery upto 500 rounds in each strategy is almost same. Furthermore, when the number of rounds increases, the number of packets delivery for different strategies also changes, and subsequently becomes constant. This is due to the draining of energy of nodes and warm hole problem nearby BS area. Among all the strategy, proposed algorithm delivers highest number of packets, due to the following reasons: (i) in intra cluster, more duty cycle assignment to near child node, results lower energy consumption, (ii) energy saving for transmission of data by optimum energy route selection, (iii) the number of hops required for packet transmission is reduced. The average number of packets delivered to the BS is 306923, 2986829, 293081, 272257, 123062, 179091, 226002 for the proposed ICIC, HEEMP, LEACH, MLEACH, SEP(30:70), SEP(50:50), and SEP(70:30) algorithm, respectively. The average packets transmission of LEACH, MLEACH, SEP(30:70), SEP(50:50), and SEP(70:30) is 97%, 95.49%, 88.70%, 40.09%, 58.35%, and 73.63% of the proposed ICIC strategy, respectively. Hence, packets delivery in the proposed strategy is highest than the other conventional approaches by considering more transmission of packets of nearby child nodes.

In Figure 9, total number of packets transmitted is computed with respect to the increasing number of sensor nodes. In this simulation scenario, higher number of sensor nodes means density of the nodes increases. As the density of the nodes increases, the following two changes occurs in the networks: (1) network energy increases as the number of nodes in the network increases, (2) signal transmission distance reduces because of higher density. As the number of nodes increases packets delivery also increases. In this paper, packets delivery for 200 to 400 nodes at different scenarios is considered. It is clear from Figure 9 that the proposed strategy transmits a higher number of packets than other strategies. The average packet delivery at different number of nodes is 385042 (ICIC), 374082 (HEEMP), 359732(LEACH), 353361(MLEACH), 139611(SEP (30:70)), 197713(SEP (50:50)), 277823(SEP (70:30)). The packets transmitted by HEEMP, LEACH, MLEACH, SEP (30:70), SEP (50:50), and SEP (70:30) is 97.14%, 93.41%, 91.76%, 36.25%, 51.34%, and 72.14% of the proposed algorithm, respectively.

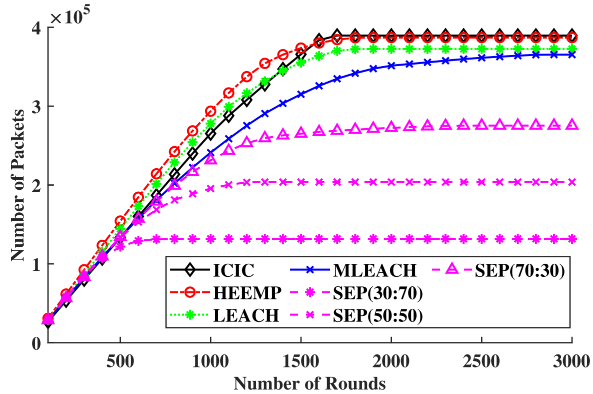

FIGURE 8. Total number of packets delivered to the base station w.r.t the increasing number of rounds (300 sensor node and area is $200 \times 200\ m^2$).

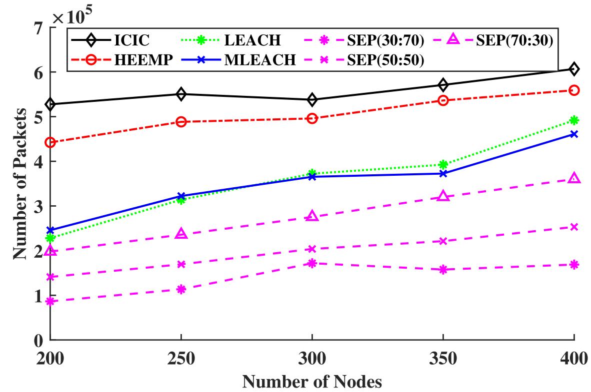

FIGURE 9. Total number of packets delivered to base station w.r.t increasing nodes density over the area of $200 \times 200\ m^2$ for 3000 rounds.

B. NUMBER OF DEAD NODES

The number of dead nodes with respect to the rounds is shown in Figure 10. When a node residual energy falls below the minimal threshold energy, it is considered as dead. Due to the constant transmission and reception of signals, the energy of sensor nodes depletes as the number of rounds increases. In Figure 11, the location of the dead nodes is shown. The nodes located near to the BS become dead because these nodes are frequently used for transmission of the received signals from previous CHs. This is known as warm hole

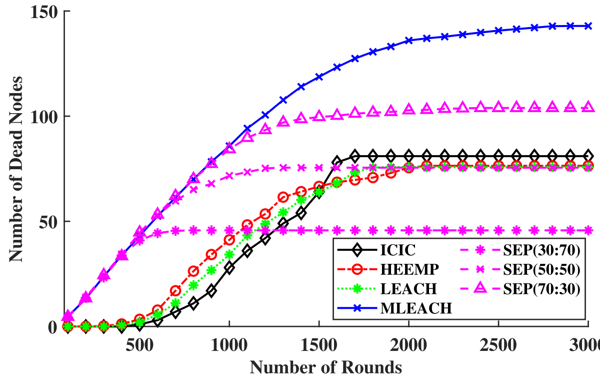

FIGURE 10. Representation of dead nodes w.r.t number of rounds at (300 sensor node and area is 200 × 200 m^2).

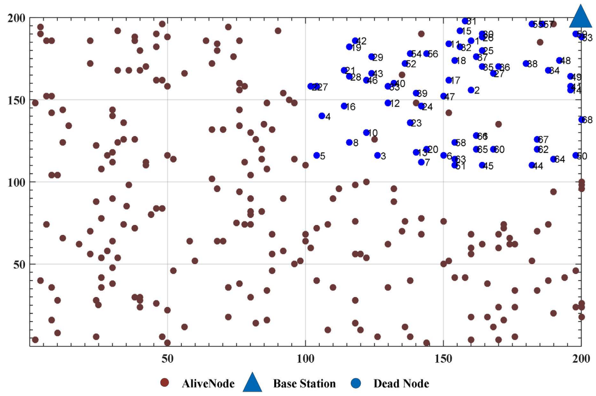

FIGURE 11. shows the sensor nodes near to the BS become dead due to warm hole problem. The order (i.e., number mentioned) of node become dead also given.

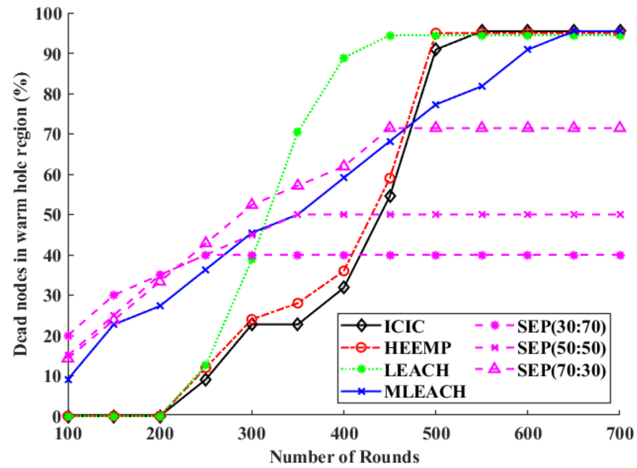

FIGURE 12. Number of dead nodes in warmhole region, i.e. X>=150, Y>=150.

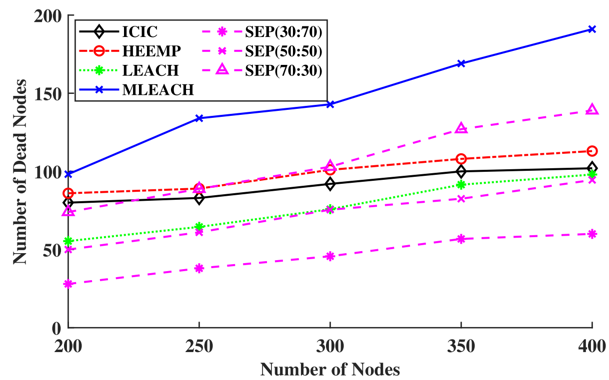

FIGURE 13. Number of dead nodes when deployed nodes increase over the area of 200 × 200 m^2.

problem and the region nearby BS is known as warm hole region. In order to evaluate the effect of warm hole problem, we have computed the percentage of nodes dead in warm hole region as shown in Figure 12. The region of Cluster 16, i.e., X>=150, Y>=150 is considered as warm hole region for simulation (see Figure 1 for cluster 16). As demonstrated in Figure 12, the proposed approach has a lower percentage of dead nodes than the other techniques over the same number of rounds. The average percentage of dead nodes in the network is 53.53% (ICIC), 54.33% (HEEMP), 62.22% (LEACH), 63.33% (MLEACH), 37% (SEP (30:70)), 44% (SEP (50:50)), 57.14% (SEP (70:30)) when the number of round increases. Sensor node energy consumption is lower and uniformly dispersed over the whole region due to: (1) more packets transmission by shorter distance node, (2) minimum energy consumption route is selected for the packets transmission.

In Figure 13 number of dead nodes is computed when number of node in the field increases. Number of dead node in MLEACH is highest because some CH node selected until that node becomes dead. Therefore, the distribution of energy consumption is heterogeneous which results very high energy drain. Moreover, the effect of warm hole also increases. Consequently, number of dead node increases. On the other hand, in SEP, most of primary nodes becomes dead which results transmission stops (see Figure 8) even energy available to the child node. Therefore, the number of dead node in SEP is least when compared to the other strategies. The average dead nodes in the network is 51.56 (ICIC), 49.9 (HEEMP), 50.7 (LEACH), 101.9 (MLEACH), 41.89 (SEP(30:70)), 64.88 (SEP(50:50)), 83.03 (SEP(70:30)) when the number of round increases. Furthermore in Figure 13, dead nodes when number of nodes in the network increases is computed. The average dead nodes are 77.93, 77.03, 69.03, 147, 45.7, 72.7, 106.3 for ICIC, HEEMP, LECH, MLEACH, SEP(30:70), SEP(50:50), SEP(70:30), respectively. In the proposed strategy, energy consumption distribution is uniform over the entire network. Therefore, the number of dead nodes are neither high nor low.

C. NETWORK ENERGY UTILIZATION

The ratio of the energy utilized by the deployed sensor nodes to the total initial energy available at the time of deployment of the nodes is defined as network energy utilization. In the designing of WSN, it is essential to utilize the available network energy as much as possible.

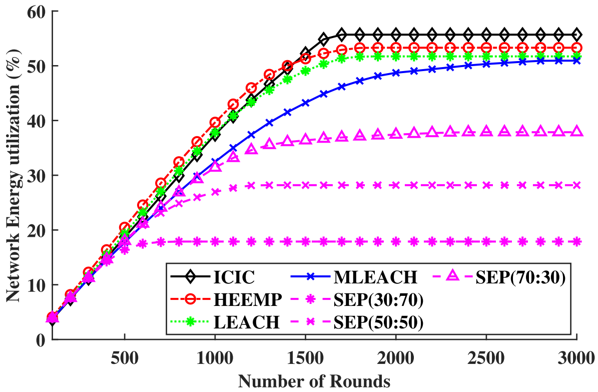

FIGURE 14. Network energy utilization w.r.t increasing number of rounds at (300 sensor node and area is 200 × 200 m^2).

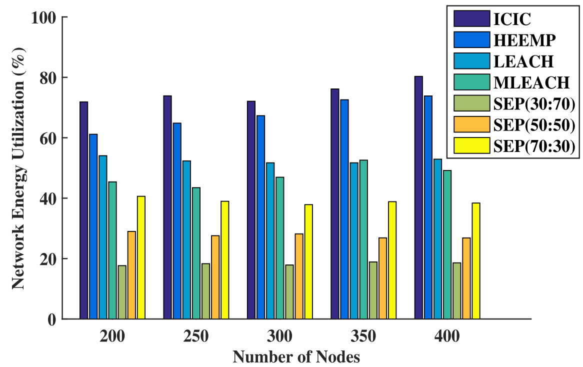

FIGURE 15. Network energy utilization when deployed nodes increase over the area of 200 × 200 m^2 for 3000 rounds.

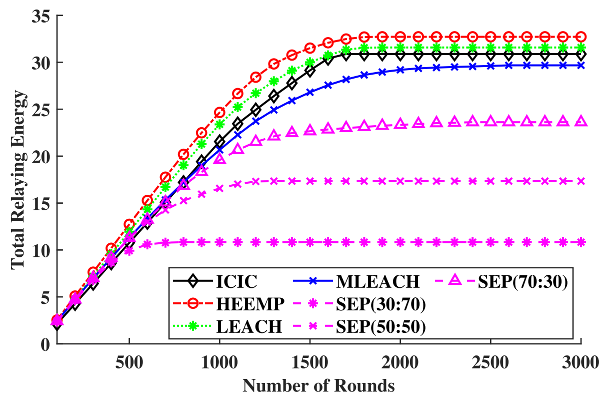

FIGURE 16. Network energy utilization for relaying when the number of rounds increases.

Network energy utilization w.r.t rounds is shown in Figure 14. Among all the strategies proposed algorithm utilizes the highest network energy. The average network energy utilization is 41.97%, 40.38%, 39.38%, 37.44%, 16.67%, 24.68%, 30.91% for proposed algorithm (ICIC), HEEMP, LEACH, MLEACH, SEP(30:70), SEP(50:50) and SEP(70:30), respectively. Hence the proposed algorithm utilizes 1.1%, 1.66%, 4.53% 25.3%, 17.29%, 11.06% more network energy than HEEMP, LEACH, MLEACH, SEP(30:70), SEP(50:50) and SEP(70:30) strategies, respectively.

In Figure 15, energy consumption is computed when number of nodes over the field increases. The average of energy consumption of different number of deployed nodes (i.e. 200 to 400) of Figure 15 is given in Table 6. The average energy utilization is 53.97%, 52.54%, 49.54%, 47.51%, 18.26%, 27.69%, 38.93% of ICIC, HEEMP, LEACH, MLEACH, SEP(30:70), SEP(50:50), SEP(70:30), respectively. The proposed strategy utilizes 1.43%, 4.43%, 6.46%, 35.71%, 26.28%, 15.04%, higher network energy than HEEMP, LEACH, MLEACH, SEP (30:70), SEP(50:50), SEP(70:30), respectively. The energy utilization of the proposed strategy is higher than the any other existing strategy. ICIC utilizes highest energy due to its uniform energy consumption mechanism over the network field. The average value of the network energy utilization is given in Table 5 and 6.

D. NETWORK ENERGY UTILIZATION IN RELAYING

In WSN multihop network, sensor node consumes energy either in its own data generation/transmission or in forwarding of received data from neighbouring CH node to the next CH/ BS. Therefore, a large amount of energy is used for relaying purpose. Figure 16 shows the energy consumption of network when node act as a relay node. It is evident from the figure that the relaying energy of the proposed energy is comparatively higher than the other strategies. Higher energy consumption in relaying is due to the fact that more packets transmission when node acts as a relay node. The average energy consumption of the total energy is 25.85 % (ICIC), 25.05% (HEEMP), 24.74% (LEACH), 22.74% (MLEACH), 10.09%(SEP(30:70)), 15.02%(SEP(50:50)), 19.27% (SEP(70:30)). The proposed strategy utilizes 0.8%, 1.11%, 3.11%,15.76%, 10.83%, 6.58% more network energy than HEEMP, LEACH, MLEACH, SEP(30:70),SEP(50:50),SEP(70:30), respectively. It is already shown in Figure 8 and 9 that more packets are transmitted to BS by proposed ICIC strategy therefore energy consumption is higher than all the other strategies.

In Figure 17 energy consumption for relaying for different number of nodes is presented. Energy consumption in relaying represents the packets forwarding to the next nodes. Higher energy consumption means higher packets transmission to the BS. As mentioned previously that number of packets transmission in the proposed strategy is highest and subsequently followed by the HEEMP, LEACH, MLEACH, and SEP protocols. The similar pattern is observed in relaying energy consumption. The relaying energy used are 32.87% (ICIC), 32.08% (HEEMP), 31.82% (LEACH), 30.98% (MLEACH), 11.3% (SEP(30:70), 17.1% SEP(50:50) and 24.15% (SEP(70:30). The proposed strategy (ICIC) utilizes 1.05%, 1.89%,21.56%, 15.76%, 8.72%, more network capacity than LEACH, MLEACH, (SEP(30:70), SEP(50:50) and (SEP(70:30), respectively. Average energy utilization in relaying is given in given in Table 5 and 6.

TABLE 5. Average values of network parameters when number of rounds increases.

Parameter	ICIC	HEEMP	LEACH	MLEACH	SEP(30:70)	SEP(50:50)	SEP(70:30)
Packets delivery	306923	298692	293081	272257	123062	179091	226002
Dead nodes	51.56	49.90	50.70	101.9	41.89	64.88	83.03
Network energy utilization (%)	41.97	40.38	39.38	37.44	16.67	24.68	30.91
Network energy for relaying (%)	25.85	25.05	24.74	22.74	10.09	15.20	19.27

TABLE 6. Average values of network parameters when number of nodes increases.

Parameter	ICIC	HEEMP	LEACH	MLEACH	SEP(30:70)	SEP(50:50)	SEP(70:30)
Packets delivery	385082	374082	359732	353361	139611	197713	277823
Dead nodes	77.93	77.03	69.02	147	45.7	72.7	106.3
Network energy utilization (%)	53.97	52.54	49.54	47.51	18.26	27.69	38.93
Network energy for relaying (%)	32.87	32.08	31.82	30.98	11.31	17.11	24.15

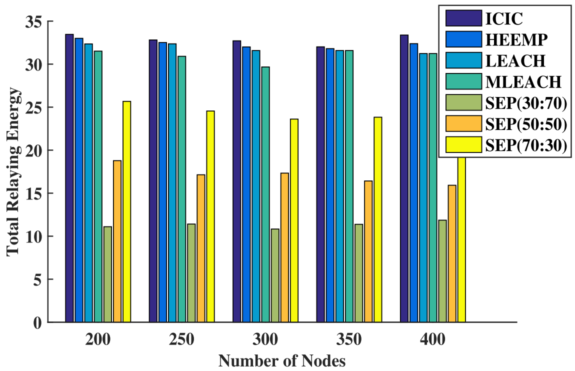

FIGURE 17. Network energy utilization for relaying when deployed nodes increase over the area of 200 × 200 m^2 for 3000 rounds.

TABLE 7. Node coordinates.

Node No.	1	2	3	4	5	6	BS
Node X coordinate	25	15	30	60	70	80	100
Node Y coordinate	20	27	40	50	65	70	100

TABLE 8. Node distance matrix.

Node	1	2	3	4	5	6	BS
1	0	12.2	20.6	46.09	63.63	74.33	109.65
2	12.2	0	19.84	50.53	66.85	77.93	112.04
3	20.6	19.84	0	31.62	47.16	58.3	92.19
4	46.09	50.53	31.62	0	18.02	28.28	64.03
5	63.63	66.85	47.16	18.02	0	11.18	46.09
6	74.33	77.93	58.3	28.28	11.18	0	36.05
BS	109.65	112.04	92.19	64.03	46.09	36.05	0

TABLE 9. Duty cycle assignment.

Round No	CH Node		Duty Cycle Assignment					
			Cluster 1 (C1)			Cluster 2 (C2)		
	C1	C2	1	2	3	4	5	6
1	1	4	0	0.53	0.47	0	0.53	0.47
2	2	5	0.53	0	0.47	0.48	0	0.52
3	3	6	0.49	0.51	0	0.45	0.55	0
4	1	5	0	0.53	0.47	0.48	0	0.52
5	2	6	0.53	0	0.47	0.45	0.55	0
6	3	4	0.49	0.51	0	0	0.53	0.47
7	1	6	0	0.53	0.47	0.45	0.55	0
8	2	4	0.53	0	0.47	0	0.53	0.47
9	3	5	0.49	0.51	0	0.48	0	0.52

TABLE 10. Total number of packets transmitted.

Round No	CH Node		Number of packets transmitted					
	C1	C2	1	2	3	4	5	6
1	1	4	0	51	46	0	51	46
2	2	5	51	0	46	51	0	46
3	3	6	48	50	0	44	54	0
4	1	5	0	51	46	51	0	46
5	2	6	51	0	46	44	54	0
6	3	4	48	50	0	0	51	46
7	1	6	0	51	46	44	54	0
8	2	4	51	0	46	0	51	46
9	3	5	48	50	0	51	0	46

VI. CONCLUSION

In this paper, a dual-mode intra-cluster and inter-cluster (ICIC) energy minimization algorithm for multihop wireless sensor network is proposed. All the strategies have compared on two different scenarios: number of rounds and number of nodes in the network. Simulation is performed on four different network parameters, i.e., number of packets delivered, number of dead nodes, network capacity utilization, and total relaying energy. Results of the simulation shows that the packets delivery of the other existing strategies have 40.09% to 93% to BS of the proposed ICIC strategy, and for number of nodes, other strategies has 36.25% to 97.14% packets delivery of the proposed strategy. Furthermore, network energy utilization is 1.1% to 35.71% higher than the other existing strategies under the different circumstances. The proposed strategy is able to perform better than the existing strategies on these metrics due to the following reasons: (1) Lower distance child nodes transmits more packets at the less energy than longer distance node using dynamic allocation of duty cycle, (2) Lowest energy inter cluster communication route is chosen for sending packets to BS. Meanwhile, in other existing strategies equal time is given to all cluster nodes without considering the energy requirement for the transmission. In future, this work can be elaborated for other WSN problems such as energy harvesting, mobile sink node problem etc.

APPENDIX
NODE COORDINATES, DISTANCES, DUTYCYCLE AND PACKETS TRANSMISSION DATA

See Tables 7–10.

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