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Intersecting Sensor Range Cluster-based Routing Algorithm for Enhancing Energy in WSN

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ABSTRACT

The primitive goal in Wireless Sensor Network is conserving energy to overcome the constraint of the limited capacity of the battery. Improving network lifetime and reduction of energy consumption are significant factors in the routing protocol design of Wireless Sensor Network. From the view of energy efficiency, it is important to select remaining energy, distance, cluster size, optimal CHs with an area of coverage and intersecting nodes radius. An energy efficiency clustering protocol proposed in this paper which elects effective Cluster Heads with optimal count and active nodes for complete coverage for optimizing the network lifetime with full coverage. The simulation result shows that Intersecting Sensor Range Cluster based Routing Algorithm achieved 21% betterment in network lifetime as compared to present energy saving technique in WSN.

Keywords - **Clustering, Routing algorithm, Cluster Head, Energy Efficiency, Wireless Sensor Network**

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I. INTRODUCTION

Wireless Sensor Network (WSN) consisting of tiny sensors able to monitor events. WSN comprised of dense autonomous sensor nodes of less battery energy, processing capacity, and limited storage space. So importance has to be given for reducing consumption energy of sensor node to extend the lifetime of the network [1]. A dense number of sensor nodes are divided into several clusters. Each cluster has a Cluster Head which collects information from cluster members upon aggregation the data is sent to sink as shown in fig 1.

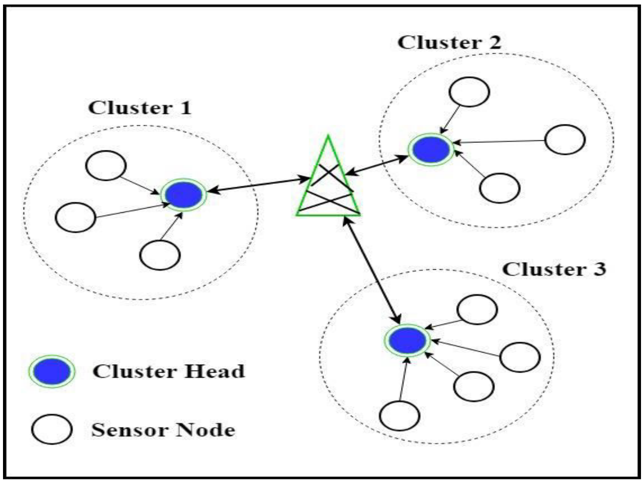

Fig 1. WSN Cluster Architecture

Modern growth in networks leads to emphasizing on energy constrained smaller, intelligent sensors. Due to recent development in engineering science led to a significant drive for energy conservation in the sensor network and their applications [2]. Numerous sensor nodes are distributed randomly in a harsh environment for sensing the target area then transmit the information to Base Station (BS)[3].

Many routing protocols are broadly categorized into the hierarchical and flat network. Sensor nodes are uniform in its role and same configuration in a flat network. In a hierarchical network group, the similar cluster and selected head will communicate with BS [4]. Multihop communication is better than single hop communication. Due to the overburden of communication among nodes and their energy shed very rapidly leads to a problem called "Energy hole problem"[5]. Sensor nodes need to cover the entire area of the target which is the most significant in some of the Wireless Sensor Network (WSN) application such as intrusion detection etc.

The unconventional method of utilizing energy leads to create an energy hole in the network. Hence a novel energy effective algorithm for solving the problem of coverage is essential for the network. Several clustering approaches in WSN don't ensure the complete coverage of the target area and leads to the death of sensor nodes [6]. There always demand to maintain complete coverage despite the death of a few nodes. Few clustering techniques neglected overlapped sensing area of sensor nodes.

Several routing protocols overcome energy hole problem but obsolete in the circumstance of coverage. Several coverage protocols concentrate on coverage but ignore energy hole problem. In WSN enhanced coverage and network, lifetime becomes important for the design of routing protocol. A new proposal called Intersecting Sensor Range Cluster based Routing Algorithm (ISRC) for enhancing network lifetime by ensuring energy and coverage simultaneously.

The paper remaining part is organized as follows: In Section II, the relevant work, Section III describes the research proposal and mathematical models. In Section. IV presents the result of simulation work with analysis. In the section, V presented a Conclusion of paper with future enhancement.

II. RELATED WORK

Many clustering protocols are proposed in the past decade to enhance energy efficiency and coverage preserving. The merits and demerits of typical clustering protocols and coverage preserving protocols are presented in this section.

In LEACH [7], Cluster heads are elected randomly for gathering and aggregating information then send to BS directly. Each round role of CH is rotated among all nodes without considering the remaining energy of nodes, optimal cluster count and average distance. Average energy, minimum path loss and degree of a node are weighing factors in a cluster based distributive algorithm for the selection of Cluster Head in the network [8]. The algorithm focus on load balancing and a number of cluster formation to conserve energy in the network but cluster head requires more energy for transmitting information directly to Base Station which depletes the energy of nodes quickly.

Cluster-based routing protocol [9] is founded on energy-aware routing design where nodes are randomly distributed. The main objective is to maintain uniform energy consumption of each node for extending the lifetime of the network. However, maintaining coverage is uncertain in critical applications. The coverage hole created when coverage significant node selected as a cluster head, as their energy drain rapidly.

In a mission-critical application accuracy of monitored data fails due to coverage holes in the network. Above algorithms fails to solve energy hole problem efficiently, although the cluster head role is rotated uniformly in the wireless sensor network. A maximum number of Clustering algorithms of earlier study focus only on sensor node lifetime ignoring complete coverage of the area. In [10] LEACH-Coverage -U protocol proposed to meet the demands of coverage problems in some real-world applications. Coverage-aware parameters are considered for network coverage preserving in the Coverage-preserving clustering protocol (CPCP) algorithm [11].

The role of cluster head, a relay node and active sensor nodes based on the condition of satisfying coverage preservation in the network. But, it increases sensor nodes computation overhead, for finding nodes location with their cost metrics.

Wang et al. proposed a Coverage-Aware Clustering Protocol (CACP) a modified method of selecting active nodes and Cluster Head for WSNs in [12]. However, a number of CH's are not proportional which leads to the quick death of few CH in the network. Tao et al. [13] proposed a Flow Balanced Routing (FBR) protocol which explores the method of multi-hop for maintaining the energy and coverage lifetime of the network. But it increases computation overhead of sensor for finding next hop before transmitting to Sink. Liu[14] proposed a scheme of average clustering called Distributed Energy-Efficient Clustering Algorithm with Improved Coverage (DEECIC). The parameters of dense deployment area, residual energy, the degree of a node are considered in DEECIC for the election of CH. Although it enhances coverage lifetime but ignored to consider the sensor activation of nodes.

Single hop transmission is inefficient in the reduction of energy consumption than multi-hop transmission [15]. In a large-scale network, multi-hop transmission is adopted in recent research [16] where aggregated data sent across multiple clusters heads instead of sending directly to the sink. Several Multi-hop transmission uses tree topology where data traffic is not shared uniformly among nodes and important node for coverage might exhaust early leads to decrease in coverage lifetime.

Tarhana et al. proposed a clustering protocol Scalable Energy Efficient Clustering Hierarchy protocol SEECH [17] studies on how to select relay nodes during clustering formation phase. Although it selects CHs and relays nodes in a different phase for reducing energy consumption but ignored the coverage importance.

Energy Aware Clustering Routing Protocol uses multilayer (EACRP) [18] uses multilayer of clusters where the width of each layer decreases near the sink. The overhead of communication is reduced but coverage performance parameters are ignored during the selection of CH in the clustering phase of the network.

In order to handle the difficulty found in the above algorithms, we suggest Intersecting Sensor Range Cluster based Routing Algorithm (ISRC) in this paper. Those nodes with optimal energy and coverage prominent are elected as cluster heads and active nodes. The appropriate selection of CHs and active sensor nodes based on cluster size, overlapping sensing range degree and cluster size consideration along with residual energy, distance, optimal cluster size count contribute more saving of energy as compared to recent existing routing algorithms. The cluster head selection more effecting near the base station which contributes more in increasing the lifetime of the network as compared to EACRP.

III. PRELIMINARIES

3.1 NETWORK MODEL

Some assumption in the proposed work which describes the network model are as follows:

- Sensors are densely deployed randomly over an area.
- All nodes are stationary with uniform initial energy, processing, and sensing.
- The unique Identification number is assigned to each sensor without aware of the location.
- Multi-hop data transmission to the BS
- Transmission range and Sensing range can be varied during the time of simulation.

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- The network model is based on 2 dimensional where transmission radius is two times greater than sensing radius.
- Data transfer in both direction among SNs
- Each node well informed with their neighboring nodes.

3.2 ENERGY MODEL

Sensor Node consists of actuators, processors, transmitter, receiver, and battery. Transmitter energy depends on the transmitter circuit which consumes energy one bit and amplifies energy consumed by sending a message over a distance to the recipient and mode of the channel.

Transmission energy is shown in equation 1

$$E_{Tx} = Ea + \mathcal{E}_{Tx} * 1 \quad (1)$$

$\mathcal{E}_{Tx}$ - Energy required per bit of message.

The energy need to send data over free space and multipath is represented in equation (2) & (3)

$$E\frac{fp}{a} = \mathcal{E}_{fs} * 1 * d^2 \quad \text{if } d \leq d_o \quad (2)$$

$$E\frac{mp}{a} = \mathcal{E}_{mp} * 1 * d^4 \quad \text{if } d \geq d_o \quad (3)$$

$\mathcal{E}$ -Represent energy spend per bit square meter.
d- distance between the sender node and receiver node
fp- free space,
mp-multi path.

The total energy required for aggregating data by all sensor nodes is represented in equation (4)

$$E_{Ag} = \mathcal{E}_{Ag} * 1 * N \quad (4)$$

N - Total number of nodes.

Receiver circuit requires energy for the message is shown in equation (5)

$$E_{rx} = \mathcal{E}_{rx} * 1 * M \quad (5)$$

M-Number of nodes

Gross energy consumed in one round is equation (6)

$$\sum_{c=1}^{c}\left(\sum_{n=1}^{Nc} Etr + E_{Ag} + E_{rx}\right) \quad (6)$$

Where c - cluster and N_C - Number of clusters.

3.3 PROPOSED ALGORITHM

The proposed work into two phase. During the first phase cluster are formed with a selection of Cluster Head(CHs) for each cluster and active nodes are identified. In the second phase Cluster Member(CMs) transfer information to respective Cluster Head then each CHs aggregate the data then send to BS.

Initially, N number of Sensor Nodes are distributed evenly on the entire area of the network. Every sensor nodes aware of their placement and number of points covered the density of node with residual energy, overlapping degree which is updated at the start of each round. Every sensor nodes announce it latest information to all node covered in its sensing range. As soon the messages are gathered all SNs determine Gross value G_V. The G_V is computed using the dimension of nodes, cluster size, intersecting nodes, and remaining energy. Intersecting degree is refers to a number of nodes involves in intersecting of sensing range as shown in figure 2.

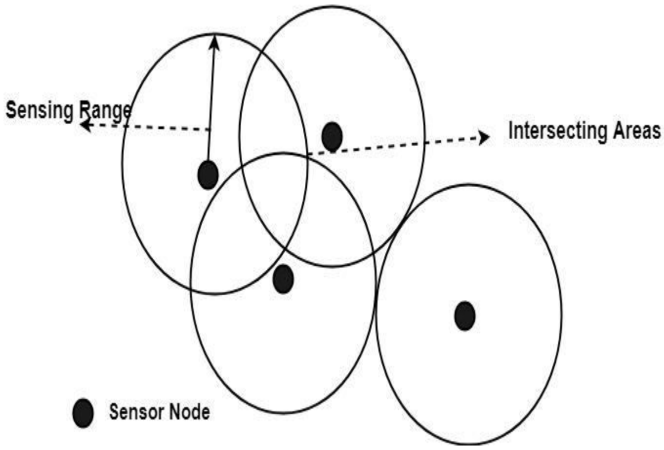

Fig 2. Intersecting Areas in WSN

Following Algorithm1 describe the process of electing CH and identifying active nodes during each round of selection process in WSN.

Algorithm 1

Step 1: Start
Step 2: Randomly spread all sensors over a network with complete connectivity.
Step 3: Calculate distance among sensor nodes using RSS (Response signal strength)
Step 4: Calculate node dimension(node capacity of covering pts), cluster size, intersecting degree, and remaining energy.
Step 5: cluster arrangement (n) [Algorithm2]
Step 6: communication phase (CH, BS) [Algorithm 3]
Step 7: If the remaining energy of a node is more than threshold energy then repeat Step4.
Step 8: Stop

Each round involves the following process. All SN's are distributed in a given area Calculate distance among each sensor nodes Find node density Nd, degree of overlapping Dolp and degree of node Dsn Compare remaining node energy Er > ET then node is allowed for the subsequent round. Net valued added parameter equation is $Nv = E\ V1 + D_{sn}V2 + D_{olp}V3 + N_d\ V4$. Nodes with an optimal value of Nv are elected as active nodes for the given area.

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Each active nodes sends packets within the radius of sense. The minimum distance node to the sink and optimal Nv value nodes within clusters are elected for CHs. The CH inform its selection to all it cluster nodes. During intracluster communication data transfer is a single hop while multihop in inter-cluster transmission.

The cluster formation is presented in Algorithm 2 as follows:

Function cluster arrangement (n) [Algorithm 2]

Step 1: Start
Step 2: Initialize energy parameters of nodes and assign a unique number and update the information.
Step 3: Compute $N_V = E\ V1 + D_{sn}V2 + D_{olp}V3 + N_d\ V4$
Step 4: Identify active nodes in the network
Step 5: Find the distance between each node to sink
Step 6: Compare remaining energy with threshold energy and elects cluster head.
Step 7: Send a broadcast message to all its cluster member in their corresponding TDMA slot.
Step 8: Stop

The values of V1, V2, V3, and V4 are 0.5,0.1,0.75.085 depends on different applications.

Function communication phase (CH,BS) [Algorithm 3]

Step 1: Start
Step 2: Find the CH distance to Base Station
Step 3: Select CH with minimum value Nv and maximum residual energy
Step 4: Identify relay nodes
Step 5: Multihop communication to Base station
Step 6: Stop

Entire is partitioned into equal distance points and SN radius covers points. The net value Nv of each node calculated whichever highest elected as active node and rest all are sleeping nodes.

The degree of overlapping involving the number of sensor nodes and covered area of neighboring sensor nodes within sensing range in selecting active nodes. Another energy parameter called the cluster size is considered for each round of selecting the CH in the network. Thus ISRC reduces the overall consumption of energy and increases the lifetime of the network.

Each member node sends data directly to CH during intra cluster operation while the relay node is chosen on the shortest path within sensing ranges of CHs. Thus the load of process aggregation and sending is distributed equally around the area without creating an energy gap and finally it improve the lifetime of WSN.

IV RESULT

The performance of ISRC is evaluated using NS2.34 Tcl network simulator and compared with Energy Aware Clustering Routing Protocol (EA-CRP). The analysis of result includes the residual energy of CHs vs. time, coverage lifetime with time, Number of dead nodes with time, network residual energy with time and number of CH alive with respect to time. The coverage lifetime refers to SN points coverage time in the network. Network lifetime represents duration from the beginning to till the minimum nodes die in the network.

Evaluation of result is done under energy and coverage network parameters. Table 1 shows the list of parameter and values used in the simulation.

Parameter	**Value**
Network Size	600
Monitoring area	100 Square Meters
Base Station location	(50,50)
Tx/Rx electronics constant	50 nJ/bit
Amplifier constant	10 pJ/bit/m2
CH energy threshold	10^{-4} J
Packet size	20 bytes
Packet rate	1 packet/s
Sensing range	13 m
Cluster radius	28 m
Initial energy (E_{int})	1J
Transmission range	30 m

Table 1. Parameter and values of simulation

4.1 TIME WITH RESIDUAL ENERGY OF CH'S

The residual energy of CHs is the remaining energy at the defined point of operation in the network. The ISRC residual energy of CHs is 14% more than EA-CRP. Fig 3. represents the network lifetime(s) with residual energy(j) of CHs.

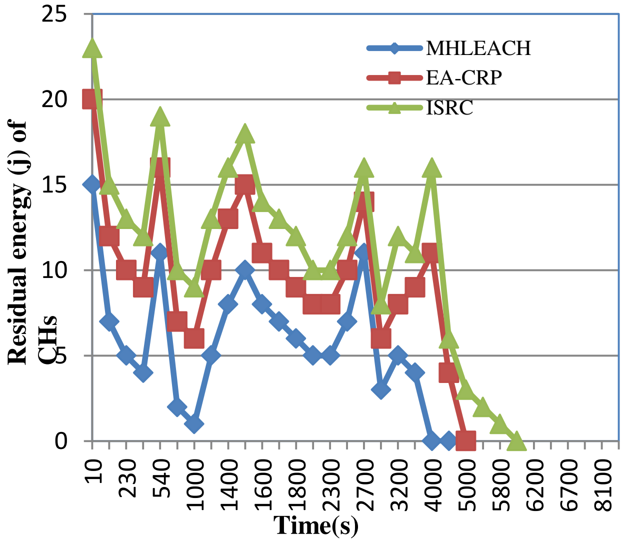

Fig 3. Time(s) vs. Residual Energy of CHs

4.2 TIME VS. COVERAGE LIFETIME

Fig 4 represents the comparison analysis amount MLEACH, EA-CRP, and ISRC routing protocol design. ISRC elects optimal CHs and efficient alive nodes so it has 7% increase in coverage lifetime as compared to EA-CRP.

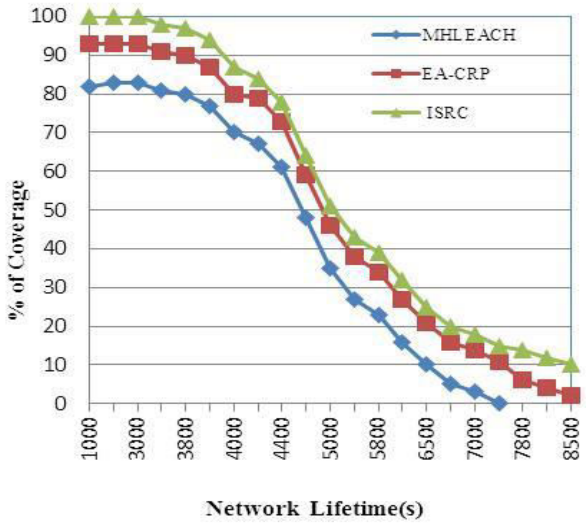

Fig 4. Network lifetime with Coverage percentage

4.3 FND, HND and LND

ISRC performance measured in terms of First Node Die (FND) time, Half Node Die (FND) time and Last Node Die(LND) time as shown in figure 5.

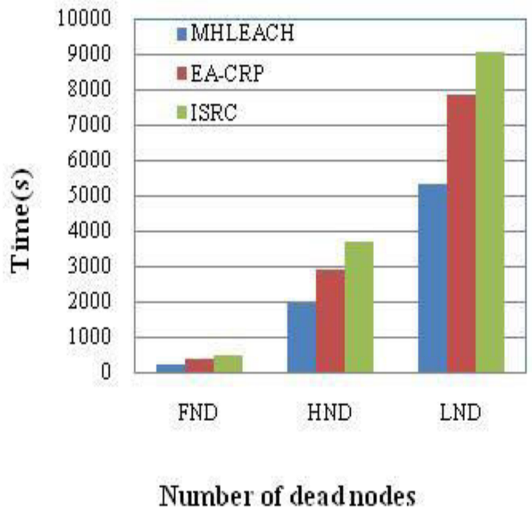

Fig 5. FND, HND and LND vs. Time

4.4 VARIED NETWORK SIZE.

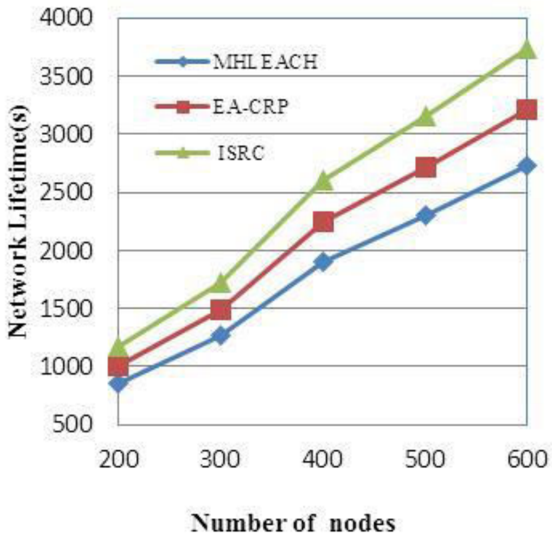

Fig 6. Number of nodes vs. lifetime(s)

The maximum number of sensors deployed is up to 600 which are varied from 200 at an interval of 100 for comparing the lifetime of the network. Our routing algorithm1 methodology on selecting cluster head and relay node based on intersecting range and avoid the extra energy for communicating the BS. It increases 20% and 13.5% more lifetime than MHLEACH and EA-CRP.

4.5 NUMBER OF CH'S ALIVE WITH TIME

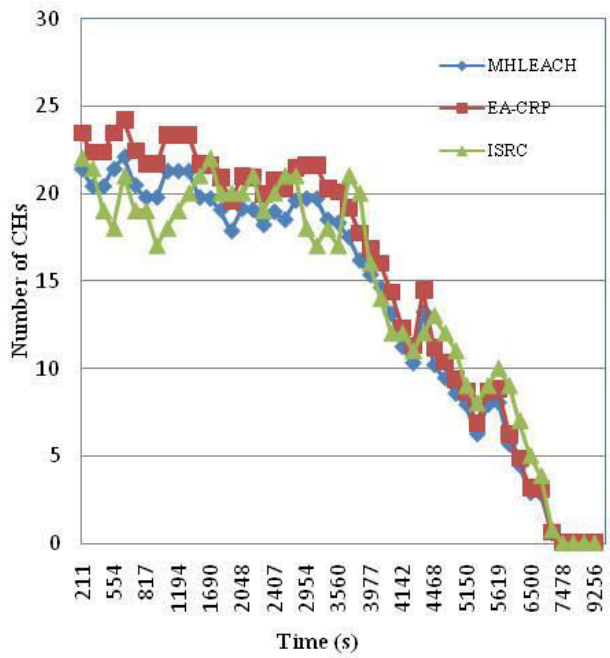

Fig 7. Number of CHs with time

The total count of CHs alive during the network process are shown in Fig 7. The ISRC shows a significant reduction in CHs count of 14% at a specific point with respect to EA-CRP.

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CONCLUSION

The objective of ISRC is to conserve battery energy using combine values of energy parameter to improve the lifetime of the network with coverage. Energy parameters include remaining energy, distance, node coverage dimension, cluster size, intersecting sensor ranges and placement of sensor nodes for reducing the consumption of energy and enhance the lifetime of WSN. A novel energy based routing design called as Intersecting Sensor Range Cluster based Routing Algorithm. An optimal count of CH's and selecting active nodes is based on the sum of energy parameters which decides the lifetime of the network. We access the functionality of ISRC using simulation with a various parameter like increasing initial energy of nodes, variation in sensor range and a different number of sensor nodes. The result of simulation shows significant improvement as compared to earlier work on energy conservation routing design in WSN.

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