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Energy-Efficient Reliable Sector-based Clustering Scheme to Improve the Lifetime of WSN

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Various hierarchical techniques such as block-based, tree-based, chain-based, and grid-based techniques have been used in wireless sensor networks for the grouping of nodes and concerted operations. According to a survey, existing chain-based clustering mechanisms, such as power-efficient gathering in sensor information systems (PEGASIS) and cluster-based low-energy adaptive clustering hierarchy (LEACH), have been appreciated for their performance in the reliable transmission of packets. However, these schemes face limitations concerning the un-balanced grouping of networks and high transmission delays. To overcome these issues, and energy-efficient reliable sectoring scheme (EERSS) is proposed. A logical grouping of sensor nodes into a sector is achieved based on a path discovery initiated by a sink node. The sector head (SH) is elected according to the distance, residual energy, node coverage, and receiving signal strength identification (RSSI) value of each node and a hop away node. A cluster-tree structure is formed, and communication is performed between the sector head and sink. The simulation results show that the scheme ensures improved packet delivery, even in a highly dense network. The simulation result analysis concludes that the proposed EERSS outperforms existing schemes concerning network lifetime and energy consumption along-with reliable communication. A mathematical model and energy consumption model are also proposed and discussed.

Keywords: cluster-chain topology, energy consumption, packet reliability, sectoring scheme, wireless sensor network

1. INTRODUCTION

Sensors are now incorporated in many applications for the smart execution of operations using networks. Sensor nodes are deployed in an application to sense and record data as required by the end-user. There are various sensors in the market for sensing physical phenomena such as sound, temperature, pressure, and motion [1, 2]. When an event occurs in a network, the sensor nodes exchange packets, owing to the event trigger. As the transmission range of these sensor nodes is limited, they adopt a hop-by-hop packet transmission approach to reach the data collection node, also called the ‘sink node’. Once data is collected at the sink node, based on the application of the end-user, the aggregated packets of information are processed for further actions. Fig. 1 shows the triggered behavior of a node during event occurrence and the packet transmission to the sink node. An event occurred node transmits its information to the sink node via an intermediate node. The data aggregation is happing towards the sink node. After this data aggregation, the received information is sent to the end-user. Quality of service (QoS) parameters such as congestion, reliability, fairness, throughput, energy reservation, scalability, and fault tolerance have

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major roles in a wireless sensor network (WSN) [3]. However, when the network is dynamic, *i.e.* the positions and numbers of sensor nodes are not fixed, QoS issues such as packet congestion, overflow, fairness issues, and enormous packet drops can occur.

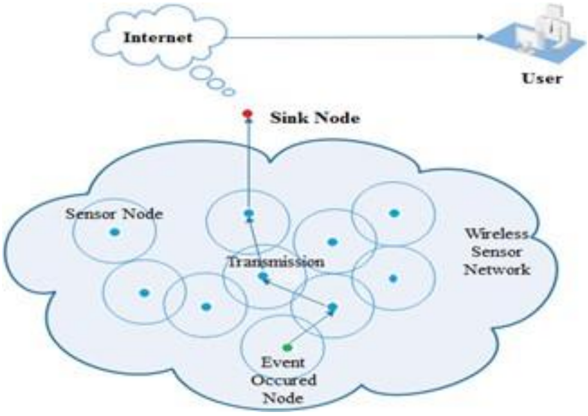


Fig. 1. Data aggregation in wireless sensor network.

The important contributions of this paper include the following four points. First, a hop away node from the sink node is being elected as a head node to quickly deliver the aggregated data to the sink node. Second is the consideration of the RSSI value of each node to check the distance and its capability to transmit the data. Third, the threshold value of energy gets used while the election of the head node, and fourth-one which is more important is node coverage. An electing a node as head from a set of a hop away node it is important to check how many neighbor nodes a covered. A simulation is performed with the existing clustering techniques for checking the performance of a proposed algorithm.

Accordingly, in this study, sector heads are elected based on a novel algorithm. The logical grouping of sensor nodes into a sector is performed based on a path discovery initiated by the sink node. Moreover, a dynamic sector head is elected, for the transmission of data from a node where the event occurred (*i.e.* the 'event occurred' node). Performance parameters such as the node density, packet size, and transmission rate are used to analyze the sensed data. The energy-efficient reliable sectoring scheme (EERSS) is implemented using a network simulator (NS-2), and the results are studied for performance evaluation. The paper is organized as follows. Section 2 provides a literature review of existing clustering algorithms. Section 3 illustrates the proposed algorithm for the EERSS, and Section 4 shows the energy model analysis used in the EERSS. Sections 5 and 6 address the implementation and performance using NS-2. Section 7 concludes the paper, with the findings and future scope of the proposed scheme.

2. RELATED WORK

There are various routing algorithms proposed for WSNs to perform communication between sensor nodes. The routing protocols are broadly classified into flat and hierarchical routing. Hierarchical routing [4] is performed with the help of different methods, *e.g.*

block cluster-based routing, tree cluster-based routing, grid cluster-based routing, and chain cluster-based routing. The advantages and disadvantages of the routing methods are shown in Fig. 2. It illustrates the various hierarchical routing techniques used in WSN. The grouping of a network into a cluster by using block-based, grid-based, tree-based, chain-based, and cluster-tree based clustering. Each routing technique has its advantages and disadvantages. Figs. 3 (a) and (b) shows the exact structure of block-based clustering as low-energy adaptive clustering hierarchy (LEACH) network protocol and chain-based clustering as power-efficient gathering in sensor information systems (PEGASIS). In a block-based clustering (BBC) scheme as shown in Fig. 3 (a), each respective cluster head (CH) [5] collects packets, aggregates them, and sends them to the sink node. The communication of packets within a cluster is called intra-cluster communication, and the communication of the packet from the CH to the respective sink is called inter-cluster communication. Sometimes, intercluster communication is also performed if the distance of one of the CHs is too far from the sink node. The election of the CH and formation of the cluster are important phases of a clustering scheme. In each iteration, a new CH is elected, based on the energy level of the nodes. Then, the newly elected CH broadcasts a message to all respective cluster nodes to inform them of its selection as the CH. There is a chance that the same sensor node can repeatedly become the CH of a respective cluster. The position of the CH may not be always nearest to the sink node [6]. Thus, it may utilize more energy to transmit and receive packets from other sensor nodes. One well-known BBC is the LEACH protocol [7, 8]. It smoothly executes the routing of packets in a clustered sensor

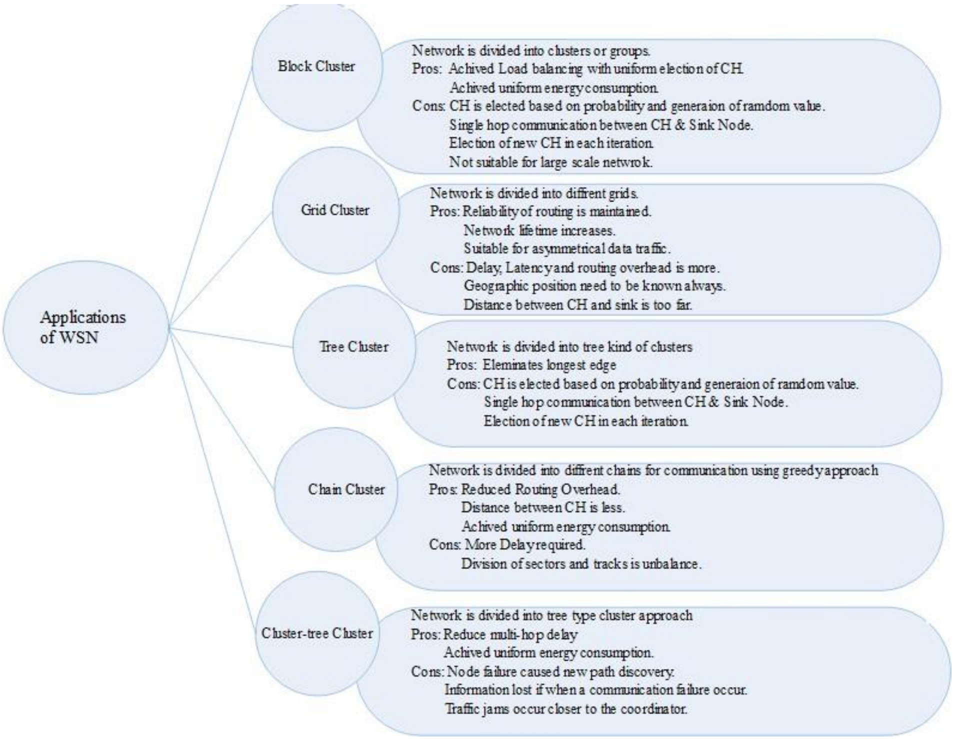
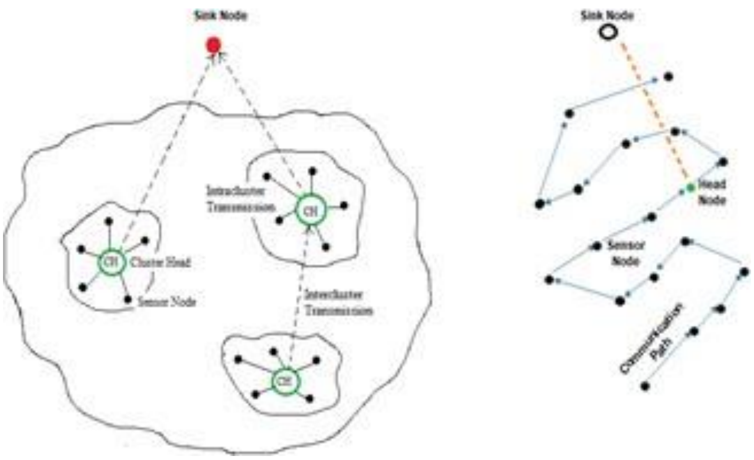


Fig. 2. Advantages and disadvantages of hierarchical routing techniques.



(a) (b)

Fig. 3. (a) Block-based clustering scheme in WSN; (b) Chain-based clustering scheme in WSN.

network. The LEACH protocol has evolved into many variant forms. The process of the LEACH protocol has two phases: a setup phase, and a steady phase. In the set-up phase, a random value is initialized to the variable, and if its value is less than the threshold value of the other sensor nodes in the cluster, the node is elected as the CH. The threshold value for the election of CH is according to Eq. (1).

$$T(n)=\begin{cases}\frac{prob}{1-prob(round \bmod 1/prob)} & \text{if } n\in G\\ 0 & \text{if } nnot\in G\end{cases} \tag{1}$$

In the above, $T(n)$ is a threshold value function, and consists following parameters:

prob = probability (in percentage) of becoming a CH; *n* = number of nodes in the network; *round* = current round value; and *G* = number of non-CH nodes.

The second phase of the LEACH protocol comprises checking for event occurrence in a particular cluster. If a packet generated towards any specific node is more than a threshold, it is considered as an event occurrence. Thus, the packets following it would be forwarded to the CH, and then to the sink.

Most researchers have identified the limitation of the BBC as being the random CH selection using the probabilistic approach. The scheme requires more control and data packets for its operations, resulting in a low network lifetime. To overcome the limitations of the BBC scheme, the chain-based clustering (CBC) technique was introduced. Fig. 3 (b) represents a working scenario for the PEGASIS protocol based on chain formation with neighbor nodes. PEGASIS [9] is a well-known CBC technique [10]. Some research articles [10-12] concluded that PEGASIS outperforms the basic LEACH protocol. It is the most optimal greedy approach for the formation of chains for the transmission of data packets. Anyone node from a generated chain could be elected as a head node or leader node, assisting the packet forwarding. The head node is elected using Eq. (2) as shown below.

$$Node_{head} = \begin{cases} i \bmod N & \text{if } N \geq 1 \\ 0 & \text{if } N \geq 0 \end{cases} \tag{2}$$

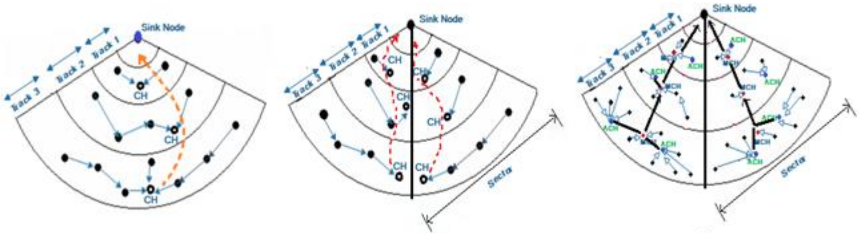
Here, i = number of current rounds; and N = total number of nodes.

The PEGASIS efficiently uses the energy in the nodes, by restricting communication to the one-hop neighbors. PEGASIS significantly improve the network lifetime along with less energy consumption [13] The three schemes shown in Figs. 4 (a)-(c), they are circular division chaining algorithm for partitioning *i.e.* the concentric clustering scheme (CCS), track sector clustering scheme (TSC), and multi-headed TSC (MH-TSC), respectively, have been introduced to overcome the limitations of CBC (PEGASIS) schemes [14]. The CCS [15] protocol has been used to balance the energy consumption ambiguity. The network division is performed based on concentric circular tracks. These circular tracks or coaxial circles are also called a cluster. The track nearest to the sink node is represented as 'level-1' or 'track-1'. The formation of the chain and election of the CH are the same as in PEGASIS. Fig. 4 (a) illustrates the process of the CCS algorithm. Each CH receives data from its one-hop neighbors. As the network is divided into horizontal tracks, the distance between the CH and sink nodes is reduced dramatically. Because of this, the CCS protocol can utilize less energy than other chain-based protocols. The proposed TSC [16] divides the network into horizontal tracks and vertical sectors. By doing so, the tracks are subdivided into sectors, as shown in Fig. 4 (b). The creation of the tracks in the TSC is the same as in. the CCS. With the help of the signal strength, location of each node, and node density of the network, the sink node sets the levels in the tracks.

A greedy approach and standard projection angle of 60° are used to divide the network into tracks and sectors, respectively. As the tracks are subdivided into sectors, more CHs are involved in the data aggregation, resulting in lower energy utilization in the nodes.

The MH-TSC [17] is shown in Fig. 4 (c). The tracks, sectors, and elections of the CH are the same as in the TSC, but the selections of the number of CHs for each track and sector are different. The scheme has tracks that are subdivided into sectors with a major CH (M-CH) and many auxiliary CHs (A-CHs). The role of each A-CH is to collect a packet from its neighbor, fuse it, and give it back to its respective M-CH for transmission to the sink node. In this protocol, the A-CHs are elected from locations nearer to the M-CH. Thus, this network structure reduces transmission delay. A comparison of the clustering schemes is provided in Table 1. [14] introduced an enhanced version of the PEGASIS routing technique, where various PEGASIS modification algorithms were explained. Various algorithms under the partitioning of a network could be performed like circular, rectangular, branch, and hybrid techniques. Here, the author also discussed the open issues so that improvements can be performed by the researchers. To enhance the efficiency of a network the data redundancy can be minimized. A reliable connection in a network needs to be considered.

An author [18] proposed an enhanced PEGASIS algorithm along-with the mobile sink to save the energy of a network. Here, the threshold distance is introduced to get optimal distance communication within a network. To maintain the good health of a network, the threshold value for the energy level is also explained. The distance of a mobile node is adjusted according to the node that wants to communicate. A virtual spider web model is proposed in [19], where a network is distributed randomly in a circular shape. Using a GPS device the position of the sensor network is stored along-with information of the neighbor node. The distance and residual energy of a node are considered while considering a node in a chain. The path repair strategy was used to maintain reliable communication in a network.



(a) (b) (c)

Fig. 4. Types of chain-based clustering algorithms in WSN: (a) Concentric clustering scheme (CCS); (b) Track sector clustering scheme (TSC) scheme; (c) Multi-headed TSC (MH-TSC).

Table 1. Processes of the sector and/or track-based clustering protocols.

Parameter	Concentric clustering Track scheme (CCS)	Sector clustering scheme (TSC)	Multi-headed (MHTSC)
Number of CHs	One CH per track/level	One CH per sector or track	One or more CHs per sector or track
Distance between CH and Sink	It is based on reduction of distance between CH and sink node	It is based on reduction of distance between CH and sinks node by dividing network into sectors and tracks	It is based on reduction of distance between CH and sink node by dividing the network into sectors and tracks
Redundant Data Transmission	Redundant data transmission caused when the reverse flow of data occurs from the sink to sensor node is overcome	Redundant data transmission caused when the reverse flow of data occurs from the sink to sensor node is largely overcome by separating large chains into smaller ones	Redundant data transmission caused when the reverse flow of data occurs from the sink to sensor node is largely overcome by separating large chains into smaller and smaller ones
CH information	Limited data gathering of information towards CH	Limited data gathering of information towards CH	Not limited data gathering of information towards CH
CH to CH Communication	Mandatory	Mandatory	Mandatory
Limitations	Unbalanced division of node density into track and sector. Election of CH is not based on RSSI value	Sometimes, even though the transmitting node is near the next track CH, it has to follow the hierarchical structure for operation; thus, it has to forward the data to its track CH and then move forward	Additional energy is needed for the election of M-CH and multiple A-CHs

The traditional hierarchical routing protocols are used mainly for the uniform distribution of a sensor network into various clusters. This saves energy during the transmission of data from one node to another. In BBC, the probabilistic approach is used for random

CH selection, and this consumes a significant amount of energy. In CBC, the greedy method is used to fix the chain structure for the transmission of data from node to node. The distance and location information is only needed for the division of the network into the different tracks and sectors. The inter-cluster communication is mandatory; without it, the protocols do not work. Thus, most of the time, the energy is utilized for the division of the network into tracks and sectors by considering the transmission slope and angle degree, respectively. Even though CBC protocols require less energy than BBC protocols, there is still room for improvement.

3. PROPOSED SCHEME MODEL

3.1 Contribution to Proposed Scheme

This paper proposes a novel EERSS for overcoming the issues in existing schemes and improving the efficiency of data aggregation. The EERSS scheme is based on a centralized approach, where information such as the distance, residual energy, RSSI value, and node coverage of each node is known to the sink node. The election of the SH follows a deterministic approach. A deterministic algorithm is used for the SH election because the election of the SH in each round consumes additional energy and time. The structure of the creation of the sector is based on cluster-chain topology. This is a novel topology get used as properties of each as mentioned in Section 2 are incorporated in the EERSS algorithm. Moreover, for each SH selection, it requires (a) an investigation of the current energy level of the node (b) for the generation of the random number (c) for comparing it with a threshold value (d) to broadcast a *HELLO* packet for notifying the new SH (e) consideration of node coverage while the election of SH. The motivation behind implementing a sectoring scheme is to use a deterministic approach for the election of the SH, to thereby save energy and time.

In the EERSS, a base station or sink node identifies the one-hop neighbor nodes using a distance calculation algorithm. Then, based on the energy levels, distances, and RSSI values of the one-hop nodes, the SH is selected, and all other nodes are considered as members of the sectors. The re-election of the SH only occurs when the energy level of the SH falls below a threshold level. A centralized approach for broadcasting the *HELLO* packet is used for path and/or route discovery in the scheme. The sink node disseminates the *HELLO* packets, which are transmitted to the elected SH in the first phase, and (subsequently) to the other member nodes in the sector in the second phase. This broadcasting of *HELLO* packets assists the path discovery, and thus when an event occurs, the packets are transmitted through the discovered route(s). As the SH is retained for a long time until there is a requirement for re-election, most of the time, the rediscovery of routes is unnecessary. Accordingly, the scheme saves energy and time. The novelty of this paper is a sectoring scheme. The differences in the operation of the sectoring scheme that is used in the EERSS algorithm as compared to an existing clustering scheme are listed in Table 2. The sectoring is achieved based on two approaches: (1) static sectoring, where the number of sensor nodes and the SH positions is static; and (2) dynamic sectoring, where the number of sensor nodes and position of the SHs is not fixed, and change in each rotation. The number of sensor nodes and SHs varies in different applications. Fig. 5 (a) shows a logical

Table 2. Processes of the sector and/or track-based clustering protocols.

Factors	Clustering Scheme	Sectoring Scheme
Location of Head	In most of the clustering scheme, the sink node is not involved in CH selection and hence is unaware of the position of the CH and cluster members in the first iteration [20]	In the sectoring scheme, the sink node initiates the SH selection process and hence is aware of the position of the SH and sector members
Election of Head	CH election is based on the following parameters: Compare the random number with a threshold value, Check probability value, Check the energy level of all other sensor nodes	SH election is based on following parameters: Distance and RSSI value of one-hop nodes, Check energy level of other sensor nodes, Check threshold value for finding the occurrence of an event.
Re-election of Head	In each iteration, new CH is elected	Existing SH is retained till it satisfies energy threshold value
Transmission to Head	Single-hop or multi-hop transmission to CH	Always single-hop transmission to SH
Routing Path	In each iteration, new path discovery for transmission	Conditional path discovery for transmission.
Inter and Intra Communication	Intercluster communication: Uses multi-hop transmission, Intracluster communication: Uses single-hop transmission	Inter sector communication: Uses single-hop transmission, Intra sector communication: Uses multi-hop transmission.
HELLO Packets	In each iteration, CH must send HELLO packets to all other sensor nodes in the network	Only in the first and conditional iterations is the HELLO packet disseminated to the SH and its sector members
Energy Consumption	There are more control messages, so more energy is consumed	The control messages are fewer, so less energy is consumed

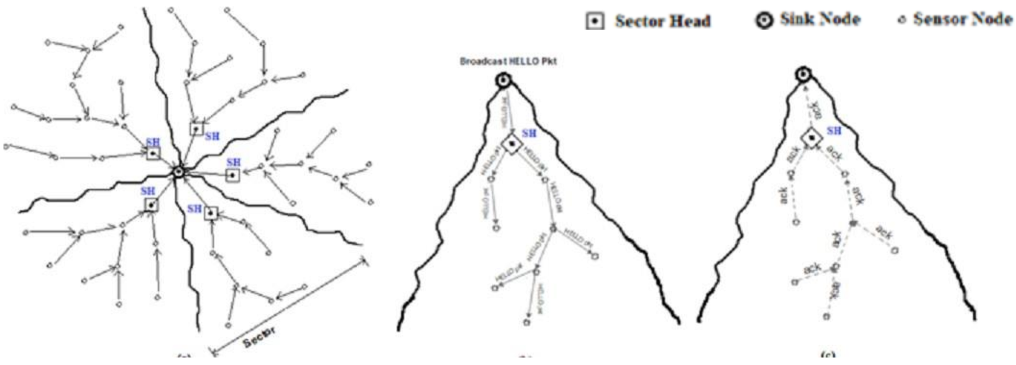


Fig. 5. Selection of node and path discovery in a sector: (a) Logical view of energy-efficient reliable sectoring scheme (EERSS) in WSN; (b) Broadcasting HELLO packet from sink to all the sensor nodes through sector head (SH); (c) Acknowledgement of HELLO packet from all sensor nodes to sink via SH.

partitioning of sensor nodes into sectors. The sector members are initially in sleep mode, and in this sectoring scheme, the nodes are only activated from the sleep mode when an event occurs. It is then the responsibility of the SH to collect packets from the 'event occurred node', aggregate the packets, and send them to the sink. The positions of the selected

SHs are always assured to be nearer to the sink, and the energy levels of the SHs are always assumed to be above the threshold level. The sectoring scheme, therefore, avoids the broadcasting of the SHs' information in each iteration. Figs. 5 (b) and (c) represent the operation of a particular sector from the EERSS.

3.2 Energy Model with Analysis

The energy model used for estimating the energy consumption of the nodes in the network is explained in this section. The first-order radio energy model for the energy consumed for packet transmission from one node to another is considered in the model. The free-space path loss is represented as $\in_{fs}$ with a d^2 power loss for one-hop or direct transmission of a packet in a network. The multipath fading is represented as $\in_{mp}$ with a d^4 power loss for multi-hop transmission of a packet in a network. In the EERSS, once an event is triggered, the packets are transmitted from the nodes to the SH of the sector, and then to the sink. The packet transmission from the nodes to SH is a multipath transmission, as shown in Eq. (3). The packet transmission from the SH to the sink node is a one-hop transmission, as shown in Eq. (4). Similarly, for one-hop and multi-hop environments, the receiving energy for the transmission is calculated as shown in Eq. (5). The total energy required for the EERSS is shown in Eq. (6). The equations for computing the transmission energy, receiving energy, and total energy needed for a '*p*' message at a distance '*d*' are as follows:

$$TEnergy_{SNtoSH}(p, d) = p*Energy_{elec} + p*\in_{mp}*d^4_{toSH} \tag{3}$$

$$TEnergy_{SNtoSink}(p, d) = p*Energy_{elec} + p*\in_{fs}*d^2_{toSink} \tag{4}$$

$$REnergy(p, d) = p*Energy_{elec} \tag{5}$$

$$\begin{aligned} SectoringEnergy_{Total}(p,d) = \sum_{j=1}^{k} TEnergy_{SNtoSH}(p,d) + TEnergy_{SNtoSink}(p,d) \\ + REnergy(p,d). \end{aligned} \tag{6}$$

In the above, $TEnergy_{SNtoSH}(p, d)$ = transmission energy needed to transmit a *p*-bit message from a sensor node to a respective SH;

$TEnergy_{SNtoSink}(p, d)$ = transmission energy needed to transmit an aggregated message from respective SHs to the sink; $\in_{mp}$ = multipath fading channel with d4power loss towards the SH; $\in_{fs}$ = free-space fading channel with d^2 power loss towards the sink node; $REnergy(p, d)$ = receiving energy needed for the complete network; and $SectoringEnergy_{Total}(p, d)$ = total energy utilised by the sectoring scheme.

3.3 Phases of Energy-Efficient Reliable Sectoring Scheme (EERSS) Algorithm

The EERSS algorithm is divided into three phases: the setup phase, locate phase, and steady phase. Fig. 6 shows a flowchart of the mechanisms of the EERSS algorithm. The phases are described below.

(a) Setup Phase: The sink node broadcasts a *HELLO* packet to all of the sensor nodes in the network. Transmission of the packet is performed using hop-to-hop communication, and the forwarding of these broadcast messages assists in the path discovery to all of the nodes in the network. The recipient sensor node sends back an acknowledgment for the *HELLO* packets. The communication path for the acknowledgment is considered as the discovered final path and is stored in the routing table. The calculated distance and RSSI value of each sensor node are also considered for analysis and it is calculated using Eqs. (10) and (11). The current energy level is also stored in a neighboring table. The working of setup phase is explained in the algorithm shown in Algorithm 1.

Algorithm 1: Calculation of distance, RSSI value, energy level of each node

Require:

n: a set of total number of sensor nodes
S: *a*, *b*, …, *n* where *S* is number of sensor node in a network
$n \in S$: a sensor node in the network (x_0, y_0): coordinator of first sensor node (s_0, s_1): coordinator of sink node
(D_a): distance of *a*th node from sink
i: number of nodes in each sector

Ensure

consider one hop away nodes
1.1 $n \leftarrow$ set number of nodes
1.2 Sink node broadcast the *HELLO* message to all members
1.3 **for** all sensor nodes do
1.4 Calculate distance between node and sink node using Eq. (8)
1.5 Calculate RSSI value between node and sink node Eq. (9)
1.6 note a current energy level of all nodes
1.7 **end for**
1.8 Calculate average distance from the sink using Eq. (10)
1.9 Calculate average RSSI from the sink using Eq. (11)
1.10 return the value calculated from equation at Steps (1.8) and (1.9)

$$ED_{(node_i, SINK_{(s_0,s_1)})} = \sqrt{(x_i - s_0)^2 + (y_i - s_1)^2} \tag{7}$$

$$RSSI_{node_i} = \frac{RxP}{Distance} \tag{8}$$

$$d_{avg} = \sum_{p=0}^{i_{node}} \sqrt{(x_0 - s_0)^2 + (y_0 - s_1)^2} + \sqrt{(x_1 - s_0)^2 + (y_1 - s_1)^2} + \ldots + \sqrt{(x_{i_{node}} - s_0)^2 + (y_{i_{node}} - s_1)^2} \tag{9}$$

$$RSSI_{avg} = \sum_{p=0}^{i_{node}} \frac{RSSI_0 + RSSI_1 + RSSI_2 + \ldots + RSSI_{i_{node}}}{i_{node}} \tag{10}$$

(b) Locate Phase: The sink uses the calculated distance, RSSI value, and current energy level of its one hop neighbors for comparison and election of the SH. In each iteration, the node with the least distance and the maximum RSSI and energy level is elected as the SH in each sector. The operation of the locate phase is explained in the algorithm shown in Algorithm 2. In this phase, the election of the SH and the member nodes in a respective sector are finalized. Here the threshold value used as a condition is based on [21]. An important parameter is node coverage used. From the set of elected a hop away, SHs is again checked with criteria like the number of nodes covered. The routing table is updated accordingly and more numbers of covered neighbors is elected as an SH.

$$NetworkCoverage(S, SH, N) = \sum_{k=0}^{N} link(k->S) \tag{11}$$

link = 1 if link exists, link = 0 if link not exist where S = Sink node, SH = Sector heads, and N = Nodes.

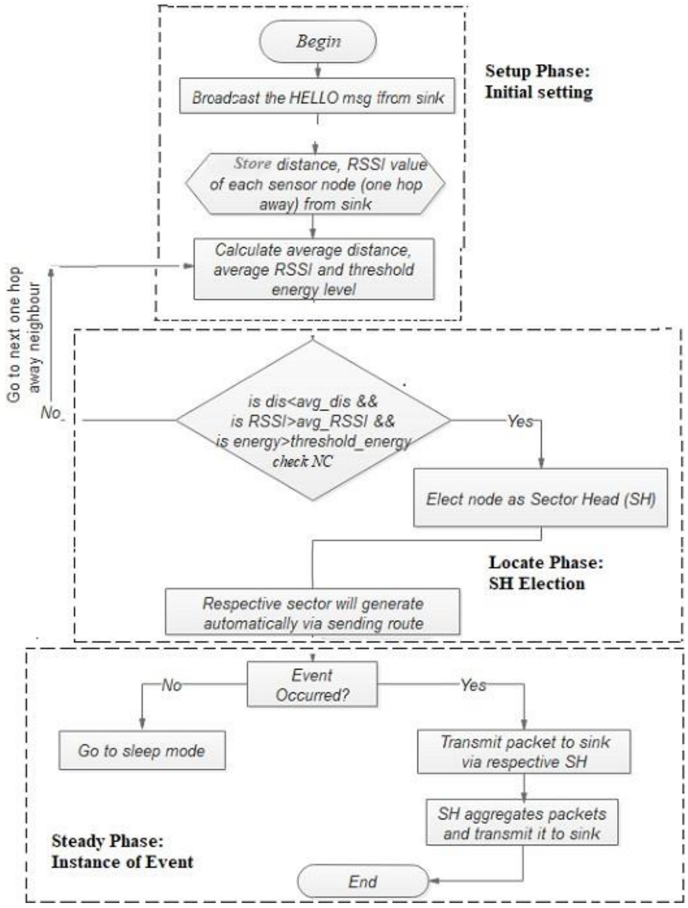


Fig. 6. Flowchart of *EERSS*.

Algorithm 2: Finding (min(d(N, S)), max(RSSI), max(energy) node from each sector for Selection of SH_i Sector Head

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Require: distance, RSSI value, energy level of each node. **Ensure:** SH_i a sensor node to be selected as sector head

1.1 *avgdis* $\rightarrow$ average distance value from all the sensor nodes.

1.2 *avgRSSI* $\rightarrow$ average RSSI value from all the sensor nodes

threhsholdenergy → threshold energy level calculated from all the sensor nodes.
Check conditions: for all one hop away nodes
    is dis < *avgdis* and
    is RSSI > *avgRSSI* and
    is energy > *threhsholdenergy*
Calculate Node Coverage(NC) of each sector using Eq. (12)
if all conditions are true then elect that node as SH.

(c) Steady Phase: The algorithm shown in Fig. 8 explains the operation of the steady phase. The instance of the event is the occurrence of an event and the transmission of the generated packets to the destination. When an event occurs, the nodes generate several packets over the threshold value to confirm the event occurrence, and to trigger the nodes in the routing path to forward the packets to the SH. The generated packets are forwarded to the respective SH via intermediate sector members and are then forwarded to the sink.

Algorithm 3: Finding occurrence of event E_0, Data aggregation at SH_j

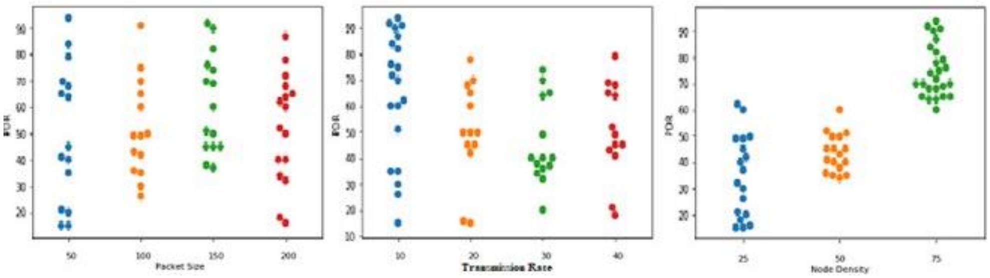
Require:
E_0: event occurred. SH_j: sector head of *i*th sector.
Ensure: initially set threshold value TH_o
    E_0 ← identification of event occurred node
    TH_o ← set threshold value
    for all sensor nodes in network **do**
        if *pkt* generated at respective node ≥ TH_o
            E_0 ← Event occurred node
        end if
    end for
    for each sector member in a sector **do**
        SH_j ← collect all packets to the sector head
end for
transfer the collected data packets to the sink node

4. PERFORMANCE EVALUATION AND ANALYSIS

The proposed EERSS scheme is implemented using NS-2, and the performance is studied. The network topology is divided into sectors, and the SHs are elected based on the algorithm described in the previous section. Table 3 shows the simulation parameters used for the implementation. A dataset is generated. The EERSS and cluster-based protocols such as LEACH, PEGASIS, the CCS, and the TSC are used for performance comparison. These protocols are more relevant to the proposed EERSS algorithm because of that they have been used for comparison. The schemes' performances are analyzed using the simulation parameters listed in table 3. The decision of consideration of node density, reporting rate, and packet size value is shown in Fig. 7. It illustrates the observations by using a swarm plot of the Packet Delivery Ratio (PDR) concerning node density, packet size, and transmission rate. Fig. 7 (a) shows a graph of packet size against PDR. The packet size varies from 50 to 200 bytes, and it has been observed that for 50-byte packet size, the network provides approximately 96% reliability. Fig. 7 (b) shows the transmission rate as a function of the PDR. It shows that for 10 packets/s, the PDR is near 95%. Fig. 7 (c) shows a graph of the node density as a function of the PDR. For a 75-node density, greater reliability is shown. This is because, with increasing node density, additional neighbors are introduced, and packets are exchanged more quickly. Thus, the observed results prove that the 10 packets/s transmission rate, 50-byte packet size, and 75-node density provide better results as compared to other configurations. So, the same configuration is being used for simulation comparison of EERSS with existing schemes.

Table 3. Processes of the sector and/or track-based clustering protocols.

Simulation Parameter	Value
Simulator	Network Simulator 2 (NS2)
Scenario Area	500 m $*$ 500 m
Node Density	25, 50, 75
Packet Size	50, 100, 150, 200
Network Traffic	Constant bit rate (CBR)
Routing Protocol	AODV
Transmission Rate	10, 20, 30, 40



(a) (b) (c)

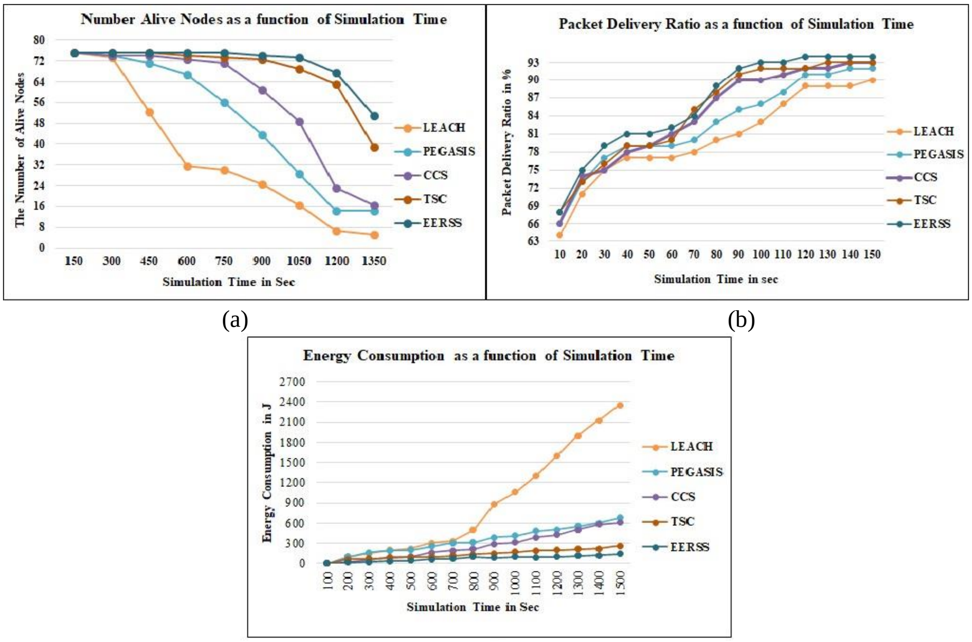
Fig. 7. PDR analysis using EERSS with (a) packet size as a function of PDR for 75-node density; (b) Transmission rate as a function of PDR for 75-node density; (c) Node density as a function of PDR.

4.1 Performance Analysis of PDR, Number of Alive Nodes and Energy Consumption as a Function of Simulation Time

Packet delivery ratio (PDR): The PDR is used to measure the reliability of the scheme. It is measured as the number of packets sent from the source to the number of packets received at the destination. The reliability of the network is analyzed using the PDR. The PDR is calculated using Eq. (8).

$$PDRin\% = \frac{\sum_{i=0}^{n} NoofPacketsReceived}{\sum_{i=0}^{n} NoofPacketsSent} * 100 \qquad 0 \le PDR \le 100 \tag{11}$$

Fig. 8 (a) illustrates the change in the PDR for simulation time. An PDR for each algorithm is calculated using Eq. (8). It has been observed that LEACH protocol giving



(a) (b)

(c)

Fig. 8. (a) Packet delivery ratio (PDR) as a function of simulation time; (b) Alive nodes as a function of simulation time; (c) Energy consumption as a function of simulation time.

less PDR as compared to others. Slightly there is improvement in percentage of PDR from LEACH to EERSS. The EERSS algorithm provides approximately 94% reliability, an increase of 4% in the PDR as compared to the other three routing protocols. In the EERSS, a larger number of packets were transferred, as the routing path was decided initially for transmission. Also node coverage factor considered while implementation of EERSS, it supports while transmission of data. This algorithm starts the transmission of packets when the path discovery and path selection are completed. The neighbor table and routing table maintain the sensor node information. Thus, the path can be redefined with the best nodes, and the SH provides a better PDR than the other protocols.

The number of alive nodes is observed for the various clustering schemes in Fig. 8 (b). It represents that the EERSS algorithm secured a greater number of alive nodes as compared to the other clustering schemes. As path discovery and path selection happens with due consult of sink node and before first iteration of network and because of that the count of alive node is more. Pre-setup of path discovery and selection along with updated routing table that holds number of nodes covered in each sectors, helps to keep alive node more. With an increase in simulation time from the initial number of seconds, a large number of nodes remain alive in the EERSS.

Fig. 8 (c) shows an analysis of energy consumption concerning the simulation time. It has been observed that when packet transmission begins, each protocol requires more energy, as there is a change in the simulation time. The energy required for transmitting and receiving a packet (along with communication) requires more energy for PEGASIS than for the EERSS protocol. This is because PEGASIS performs the election of the CH based on random constraints anywhere in a chain; as such, the packet size and packet distance do not work well in it. In contrast, the EERSS requires less energy owing to the sector selection, which helps to select an SH with less distance from the sink and more energy than the threshold. As node coverage information is stored inside a neighbouring table at initial iteration and because of this less energy utilized for identification of neighbouring node. The power consumption is less in the EERSS; accordingly, the EERSS helps improve the lifetime of the network.

5. CONCLUSION AND FUTURE SCOPE

Each clustering scheme has its advantages and disadvantages. The proposed EERSS algorithm was designed to overcome the limitations of existing schemes like the distance between the head node and sink node, a lifetime of the network along-with reliable communication. The novel algorithm for SH selection and the working of the EERSS scheme is based on (a) the RSSI value, distance, and energy level; (b) one-hop communication with the sink node; (c) one-time formation of sectors; and (d) broadcast-initiated path discovery and path updating in the routing table; (e) consideration of node coverage. These five points together were used while implementation of EERSS algorithm. This has not happened before in clustering techniques. The performance of the EERSS is studied and compared with LEACH, PEGASIS, CCS, and TSC, with implementations in NS-2. It has been observed that EERSS algorithm is showing near about 87% number of nodes are alive while transmission of data as compared to LEACH. It is a metric to assess energy efficiency of network. As more number of nodes alive in-network lesser energy required as larger number of neighbor nodes are present. It reflects around 94% of energy savings in communication as comparative with LEACH. The EERSS consumes less amount of energy as it uses single hop communications. These factors are directly related to PDR as 4.4% improvement in transmission packets. The EERSS consumes less energy, as it uses single-hop communication. It would be suitable for applications where reliable packet delivery is important. Also, the energy consumption of the sectoring scheme is much less than that of the other clustering schemes. Therefore, the network lifetime is increased. In the future, the performance of the EERSS algorithm can be improved by implementing this scheme, and by using an optimization algorithm to prove that the elected number of SHs is in the optimal number and location.

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