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Article

EACR-LEACH: Energy-Aware Cluster-based Routing Protocol for WSN Based IoT

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Abstract: Internet of Things (IoT) is a recent paradigm to improve human lifestyle. Nowadays, number devices are connected to the Internet drastically. Thus, the people can control and monitor the physical things in real-time without delay. The IoT plays a vital role in all kind of fields in our world such as agriculture, livestock, transport, and healthcare, grid system, connected home, elderly people carrying system, cypher physical system, retail, and intelligent systems. In IoT energy conservation is a challenging task, as the devices are made up of low-cost and low-power sensing devices and local processing. IoT networks have significant challenges in two areas: network lifespan and energy usage. Therefore, the clustering is a right choice to prolong the energy in the network. In LEACH clustering protocol, sometimes the same node acts as CH again and again probabilistically. To overcome these issues, this paper proposes the Energy-Aware Cluster-based Routing (EACR-LEACH) protocol in WSN based IoT. The Cluster Head (CH) selection is a crucial task in clustering protocol in WSN based IoT. In EACR-LEACH, the CH is selected by using the routing metrics, Residual Energy (RER), Number of Neighbors (NoN), Distance between Sensor Node and Sink (Distance) and Number of Time Node Act as CH (NTNACH). An extensive simulation is conducted on MATLAB 2019a. The accomplishment of EACR-LEACH is compared to LEACH and SE-LEACH. The proposed EACR-LEACH protocol extends the network's lifetime by 4%–8% and boosts throughput by 16%–24%.

Keywords: Cluster head; clustering protocol; internet of things; routing metrics; wireless sensor networks

1 Introduction

The Internet of Things (IoT) is a collection of objects linked to the Internet that can share data from one to another [1–6]. Kevin Ashton coined the term “Internet of Things” in 1999. By 2025, it is projected that 30 billion devices will be connected to the Internet. The emerging trends in IoT are driven by Artificial Intelligence, Machine Learning, Blockchain, 5G, etc. The IoT applications are smart home, smart healthcare, precision agriculture, industrial automation, etc., [7–10].

Advancement in low-power wireless networking, the emergence of Complementary Metal-Oxide Semiconductor (CMOS) technology and miniaturized sensing devices paves the way for landscaping Wireless Sensor Network (WSN) [11–15]. It is a wirelessly interconnected device capable of sensing the physical phenomenon of the target region and can communicate through wireless links. The exciting features of sensor devices address the gap between physical events and the digital world. Sensors placed in WSN sense the environment collects data, processes them, and delivers the aggregated data towards the sink [16–20]. The reference architecture of a wireless sensor network is shown in Fig. 1.

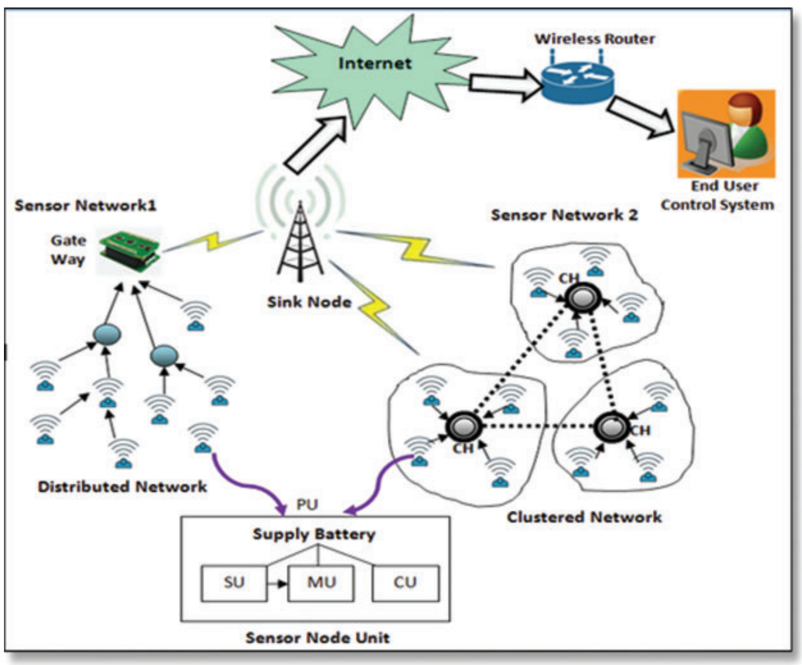

Figure 1: Reference architecture of wsn

The significant and tiny physical entity of WSN is a Sensor Node (SN). Irrespective of their types, each sensor is comprised of four basic units, namely Sensing Unit (SU), Microcontroller Unit (MU), Communication Unit (CU) and Power supply Unit (PU) [21–28]. SU is responsible for sensing the target area and converts the analog data from the field into digital form using an ADC converter. The processing element of the sensor node includes a microcontroller and memory unit, which carry out data manipulation and storage of processed information. CU consists of communication resources, more often restricted radio range and a small battery in PU furnishes the power to the whole SN unit [29–31].

WSN comprises two types: Distributed Network (DN) and Clustered Network (CN) based on node communication. In DN, SN behaves autonomously and are interconnected with each other for forwarding their data to sink. It does not require a monitoring node, and each node can analyse the data it receives before passing it on to its neighbor. Nodes closer to the sink may drain their energy quickly due to bottleneck problems [32–34]. In CN, the sensor node forms the cluster based on their communication range. In each cluster, any node will act as a Cluster Head (CH) responsible for forwarding the aggregated data from the sensor field to the sink node. In general, sensor nodes in each cluster are connected with CH through a single hop. CH can communicate with each other to share the information from the base station. CN can be divided into Hierarchical CN (HCN) and Distributed CN (DCN) based on how CHs are in touch with the sink node. In HCN, CHs form a hierarchy, and the CH, which is in the top-level hierarchy, will have direct contact with the sink, whereas, in DCN, CH can send the data to its neighbor CH and then processed and forwarded further towards its sink [35–38].

Sinks are essential in WSN because they allow communication between the end-user and the sensor field. It has high energy and processing ability. The sink acts as an access point to gather the sensory data from the target area, process them, and convert them as helpful information to the end-user control system through the Internet and wireless network.

The Internet of Things (IoT) is a platform in which things with sensors, transducers, and processors connect significantly. The WSN innovation is an essential element of IoT since it comprises several sensor devices interacting with the actual world via communication networks. Due to the boundless intervention of sensors in almost all sectors, the applications of WSN are growing every day. Nevertheless, contemporary works deemed WSN applications are entitled IoT applications without differentiating the new aspects characterizing this term.

The diverse variety, Inexpensive and Ad-hoc nature of sensors creates more attention in launching WSN in remote areas where the wired communication is not possible easily. They can be supervised by the users for making a timely decision. In particular, the convergence of WSNs and the IoT enables a ubiquitous interaction of things that have enormous applications both in private and public domains. Especially in a hostile environment like dense forest and chemical industry, significant applications such as forest fire detection, animal tracking system environmental pollution monitoring, industrial control systems and landslide prediction, unmanned battlefield monitoring, video camera surveillance in crowd areas, natural disaster rescue, smart agriculture, smart cities, health monitoring and other business applications were created.

Nodes in a WSN-based IoT are tiny, inexpensive, and energy-efficient, allowing for efficient data transmission. Once dispersed throughout the monitoring region, energy-constrained batteries in sensors become difficult to recharge. In comparison with sensing and computing stages, WSN uses a lot of energy during data transmission. Network life is the biggest problem, and hence adequate routing for early transmission is essential. Since the network's lifetime remains an important need to extend the network functionality, the routing protocol must efficiently use the power because of the implementation of WSN with small energy sensor nodes.

The whole topology of the WSN is divided into sub-regions via the technique known as clustering, enabling efficient transmission of data and the extension of network life. As energy efficiency is an essential part of network life, clustering is more critical. The clusters are the structured WSN units. Furthermore, the extensive structure of the networks is divided into clusters to facilitate the task of communication. In general, each cluster comprises CH, which gathers recently observed data inside the cluster through the member nodes and returns the aggregated data to the BS. Nodes can forward their sensed data to CH, known as intra-cluster routing, whereas CHs can forward the aggregated data towards the sink known as inter-cluster routing. If SN must minimize its power use, its data packets should first be sent to CH's rather than sent to the sink promptly.

In WSNs, single- or multi-hop communication is used to collect and forward data to the base station via a routing mechanism. To ensure longer network life and decrease energy depletion for the WSN, the cluster head role alternates between each member of a group. LEACH is a well-accepted protocol in WSN to facilitate network lifetime enhancement via clustering the network for data collection [39–42]. The two main procedures involved in increasing network life are Clustering and Sleep Scheduling.

The WSN based application follows the single hop or multi-hop data transmission in routing. Some applications like environmental monitoring, temperature monitoring and nuclear power plant monitoring are not necessary to send individual sensors and that may create duplicate data. Therefore, cluster-based routing is one of the active research areas in WSN and IoT. From the literature review, the development of a cluster-based routing protocol decreases the delay, increases the network's lifetime, and increases the throughput. These are strong motivational points to select the LEACH as the standard baseline protocol. However, LEACH is a standard clustering protocol existed with specific problematic issues as follows:

- LEACH makes no attempt to address the sensor node's location or the number of cluster heads in the network.
- Direct communication of CH with BS may drain the energy quickly if the distance between them is too high.
- CH's battery degraded more rapidly than others due to the high energy required for data transmission and fusion.
- The head of the cluster is constantly on and if CH is destroyed the no use of gathered data within the clusters and it will not be communicated to BS in any means.
- Without optimal and energy consciousness choice of cluster head (CH) exhibiting the loss of energy between sensor nodes.

To overcome all of the LEACH protocol's restrictions, this paper proposes EACR - LEACH as a way to extend the network's lifetime. During the CH selection process, it takes into account the factors NoN, RER, distance, and NTNACH.

The authors key contribution in EACR-LEACH as follows:

- An extensive literature review conducted that it discusses various LEACH protocols, advantages, accomplishments and limitations.
- In EACR-LEACH protocol, the authors introduces new metric, namely Number of Time Node Act as CH (NTNACH) to extend the network's lifetime.
- The simulation results indicate that the proposed EACR-LEACH enhances network performance in terms of network lifespan, packet delivery ratio and throughput.
- Design and development of EACR-LEACH for choosing the right CH to increase the network lifetime and packet delivery ratio.
- The simulation is conducted using MATLAB 2019a, and the effectiveness of EACR-LEACH is compared to that of two other clustering protocols, LEACH and SA-LEACH.

The remainder of the paper is structured as follows: Section 2 addresses the related work. Section 3 discusses the system preliminaries. Section 4 presents the EACR-LEACH protocol. Section5 discusses and compares the proposed with respect to the existing protocol. Section 6 concludes the paper and discusses the future work.

2 Related Works

This section provides a detailed discussion of various energy-aware LEACH protocols in WSN based IoT. Furthermore, these works address the problem, techniques, accomplishments, and limitations.

Mehra et al. [43] proposed SE-LEACH which considers number of nodes, distance from BS, remaining energy and power dissipation are the parameters to select cluster head efficiently. In two different scenarios the simulation experimentation conducted by placing the BS at the center and in some far distance from the clusters. Though it uses network load balancing, CH election does not include the number of times the node was elected CH and includes the process of calculating its rank.

Salem et al. [44] presented an Enhanced LEACH protocol for extending the lifespan of wireless sensor networks. The CH selection is made on the basis of the distances between each node and the CH and the BS. It is not involved on how close the non CH nodes with CH. Simulation work is carried out on the proposed extended LEACH with original LEACH. It extends the traditional LEACH with the new approach in CH selection but failed to include the residual energy of a node, mobility of a node and power dissemination.

Baniata et al. [45] proposed a novel MIMO-HC protocol for IoT. In MIMO-HC, Sub-optimal rout generated between cluster heads proportional to their range to the central station is in operation. The MIMO-HC attains minimum power utilization and improved system duration contrast to its counterpart approaches. This is accomplished by the energy consumption of CH in MIMO-HC protocol is 40% reduced than UN-LEACH. However, this protocol only considers the RER of a node and ignores the transmission distance between nodes. The more calculation for sub-optimal cluster maintenance even destroys energy of the network.

Ouldzira et al. [46] proposed MG-LEACH, which utilises an intermediary CH to transfer the data packets from CM to Sink. In MG-LEACH, BS divides the nodes into subgroups during the placement of node in the field. To conserve energy, node groups are allowed to work alternatively. However if all the nodes in one subgroup is poor in energy and will not satisfy the energy threshold condition leads to regrouping that is not addressed in MG-LEACH.

Kumar et al. [47] proposed an MM-LEACH protocol that addresses the varying node density in each cluster by fixing the average N nodes in each CH to better load balancing in the network and maintain a good network lifetime. N is computed by dividing the total number of nodes by the total number of CH. While selecting the CH, only the energy threshold is taken into account but not feasible solution for many situations like scalability and load balancing the networks. BS's intervention causes an overhead in cluster formation.

Behera et al. [48] proposed modified LEACH for IoT application. It uses the threshold value during the CH election in the network nodes. Thus, conserve the energy among nodes uniformly in the network. The accomplishment of modified LEACH is compared with standard original LEACH. Therefore, it enhances the lifespan of the network. However, the nodes drain the energy after certain rounds during the data exchange.

Gou et al. [49] proposed an Energy-Efficient Clustering Routing (EECR) in WSN. The EECR is an improved version of the LEACH protocol. It has two stages such as clustering and data transmission stage. The clustering stage considers four parameters, namely residual energy, number of CH, base station distance, round number that nodes are selected as CH. Later, the data transmission stage is used the free space or multipath model to exchange the data from CH to the sink. The simulation is conducted using the MATLAB simulator. The performance of the proposed EECR algorithm is compared with LEACH, LEACH-C and HEED. However, It is not suitable for large scale because the CH is selected randomly.

KMO Nahar et al. [50] proposed a modified probability function for cluster head election in LEACH (MPF-LEACH) protocol. The primary aim is to select the CH using residual energy to prolong the lifespan of the network. This paper is introduced the threshold value, which is based on the probability value. The enhancement is mainly focused on extending the lifespan of the network and increases the throughput. The main objective of this method provides the maximum probability value to elect CH, the node which has more residual energy. The simulation is conducted using the MATLAB simulator. The performance of the proposed MPF-LEACH is compared with LEACH. Thus, the proposed MPF-LEACH is extended the lifespan of the network than LEACH. However, the threshold functions prohibit CH re-election for any sensor considered to be low on energy.

Hnini et al. [51] proposed Improved W-LEACH Decentralized protocol in WSN. This paper is proposed the game theory concept in W-LEACH protocol to choose appropriate CH. The simulation is conducted using MATLAB simulator. The efficacy of W-LEACH with game theory is compared to W-LEACH and LEACH. The proposed W-LEACH with game theory is extended the lifetime the network and throughput. However, it is depleted the energy after certain rounds.

Various LEACH protocols are discussed to prolong the lifespan of the network. From the literature review, we observed the limitations are follows: some of the protocols are not considered the important routing metrics like residual energy, distance, etc, probability based CH selection causes early depletion the network nodes and it supports the small network area due to the coverage the sink. Hence, the network nodes drain the battery earlier in the network. To increase the network performance, this paper proposes an EACR-LEACH in WSN based IoT. Thus, EACR-LEACH extends the overall network performances in terms of network lifetime and packet delivery ratio.

3 System Preliminaries

3.1 Network Model

The network nodes are highly resource constrained. We consider that there are 'N' nodes and one sink in the network. The nodes are distributed at random, while the sink is located at the network's center [52,53]. Initially, the proposed EACR-LEACH selects the right CH among the network nodes using the network parameters, namely RER, NoN, Distance and NTNACH. Later, the CH gathers the data and aggregated data transfers to the sink. Fig. 2 illustrates the EACR-LEACH network model.

The EACR-LEACH is considered the following assumption.

- Nodes are placed randomly and sink node placed at the center.
- All the nodes have equal energy.
- It supports the single hop data transmission between CH and Sink.

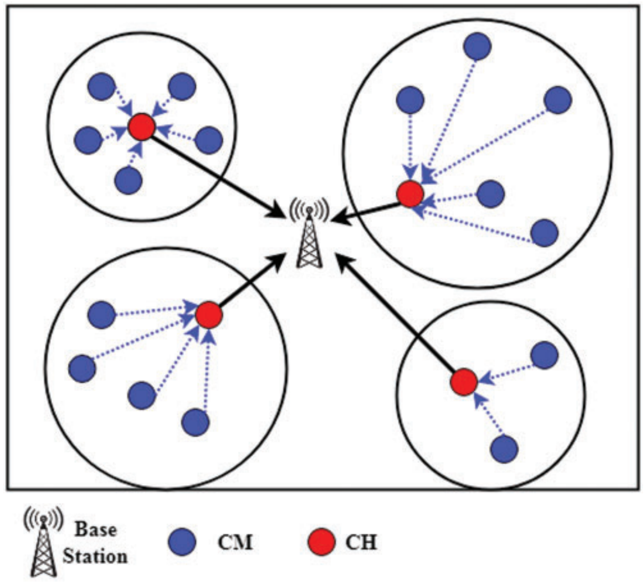

Figure 2: : EACR-LEACH network model

3.2 Energy Model

The EACR-LEACH is adopted the simplified channel model for transferring the data from the source to sink [52]. Fig. 3 illustrates the EACR-LEACH energy model.

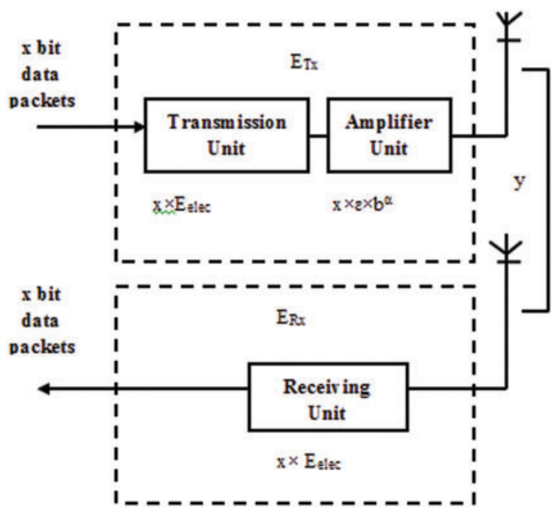

Figure 3: EACR-LEACH energy model

The amount of energy required to carry x bits from node m to node n is proportional to the distance y, and the formula for calculating this amount of energy is provided in Eq. (1).

$$E_{TX}(x, y) = xE_{elec} + y\varepsilon b(m, n)^{\alpha} = \begin{cases} xE_{elec} + x\varepsilon_{fr} y(m, n)^2 & \text{where } y(m, n) < y_0 \\ xE_{elec} + x\varepsilon_{mp} y(m, n)^4 & \text{where } y(m, n) \geq y_0 \end{cases} \quad (1)$$

The threshold value of the distance Y_0 is computed from Eq. (2).

$$Y_0=\sqrt{\frac{\varepsilon_{fr}}{\varepsilon_{mp}}} \tag{2}$$

The quantity of energy consumes to receive x bits from the node m and its calculation is given Eq. (3).

$$E_{RX}(by) = yE_{elec} \tag{3}$$

4 The Proposed Energy Aware Cluster Routing (EACR-LEACH)

The proposed EACR-LEACH protocol is designed to mimic the behaviour of the LEACH protocol. It is divided into two phases: the setup phase and the steady phase. In general, the LEACH picks the CH on the basis of a random number between 0 and 1, with the higher value being preferred. The sensor node will behave as CH if the random number is less than or equal to the threshold. The threshold Thres(node_id) value is calculated and it is given in Eq. (4).

$$\text{Thres(node\_id)} = \begin{cases} \dfrac{CH_p}{1 - CH_p\left(r - CH_p \times \text{mod}\left(\dfrac{1}{CH_p}\right)\right)} & n\ e\ S \\ 0 & \text{otherwise} \end{cases} \tag{4}$$

where CH_p indicates the percentage of nodes act as CH, r indicates round, S indicates set of non CH nodes in the network.

This process is carried out until CH is selected in the network. After CH selection, the CH broadcasts the message to the neighbour node. The CH's forms the cluster based on the CM's response. Finally, the CH sends the aggregated data to the sink.

In EACR-LEACH, the CH selection is based on the Objective Function (OF). The OF is a function that used to provide the maximum profit based on the conditions. In EACR-LEACH, the OF considers the metrics, namely RER, NoN, Distance and NTNACH.

4.1 CH Selection Metrics

4.1.1 Residual Energy (RER)

RER indicates the amount of available energy in the network nodes and its calculation is given in Eq. (5).

$$\text{RER(i)} = \frac{E_i - E_s}{E_i} \tag{5}$$

where i indicates the node id, E_i and E_s indicate initial and spend energy respectively.

4.1.2 Number of Neighbours (NoN)

The NoN indicates the number of neighbour's is located near by the node. The node i is calculated the NoN and it is given in Eq. (6).

$$\text{NoN(i)} = \frac{\text{Number of Neighbors}}{\text{Total Nodes}} \tag{6}$$

4.1.3 Distance

The distance is a metric that indicate the distance between CH and the sink in the network. The distance is calculated and it is given in Eq. (7).

$$\text{distance(i)} = \text{distance(i, Sink)} \tag{7}$$

4.1.4 Number of Time Node Act as CH (NTNACH)

The NTNACH is a metric that indicates the ration between how many times the particular node acted as CH among total number of nodes in the network. The node i is calculated the NTNACH and it is given Eq. (8).

$$\text{NTNACH(i)} = \frac{\text{Number of times node act as CH}}{\text{Total nodes}} \tag{8}$$

4.2 Object Function (OF)

The Objective Function (OF) helps to find a maximization or minimization solution. The OF is calculated based on the routing metrics, RER, NoN, Distance and NTNACH. In EACR-LEACH, the metrics RER and NoN are Maximization property and Distance, NTNACH are minimization property. Therefore, we are considered that all the metrics are minimization property. The EACR-LEACH protocol selects the minimal OF value contained node is elected as CH. We have conducted the simulation several time and varied the weight values among all the metrics. Finally, the weight values w_1, w_2, w_3 and w_4 are 0.25, 0.25, 0.25 and 0.25 respectively. The OF calculation is given in Eq. (9).

$$\text{OF(i)} = w_1 \times (1 - \text{RER(i)}) + w_2 \times \text{Distance(i)} + w_3 \times (1 - \text{NoN(i)}) + w_4 \times \text{NTNACH(i)} \tag{9}$$

The mechanism of EACR-LEACH protocol is given in Algorithm 1.

Algorithm 1: EACR-LEACH

Input: Number of nodes N
Output: best CH
For each (N)
Setup phase
    Compute the Thres(i) using RER, Distance, NoN and NTNACH
  If Thres(i)< Threshold value **then**
    Node 'i' acts as CH
    CH broadcast the message to CM's
  Else
    Node 'i' acts as CM
End
Steady phase
    CH gathers and aggregate the CM's data
    CH transfers the data to sink
End

The work flow of EACR-LEACH protocol is shown in Fig. 4.

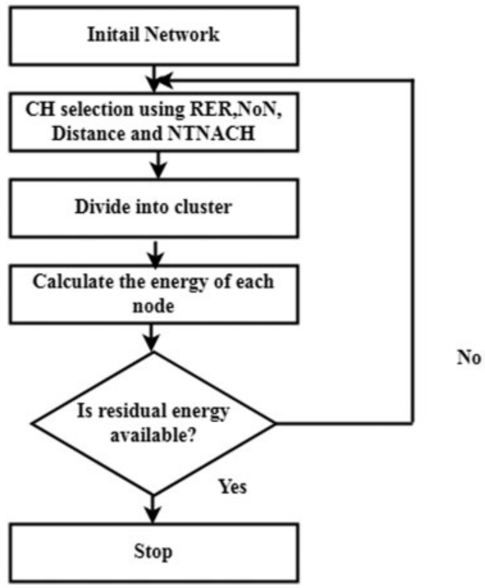

Figure 4: Work flow of EACR-LEACH

5 Result and Discussions

The efficacy of the proposed EACR-LEACH protocol is compared with LEACH and SE-LEACH. The simulation is conducted using MATLAB 2019a. We have taken the total number of nodes are 100 and one sink deployed over the network region of 100 m × 100 m. The Sink is placed at the position of (50 m, 50 m). The optimal number of CH percentage is 10%. The node's initial energy is 0.5Joule. The maximum number of round is 2500. The packet size is 4000bits. The simulation parameter and default value is given in Tab. 1.

Table 1: Simulation Parameters and default value

Parameter	Default Value
Simulation tool	MATLAB2019a
Number of nodes	100
Number of sink	1
Multipath model	0.0013 pJ/bit/m^4
Electronic circuitry (E_{elec})	50 nJ/bit
Packet size	4000 bits
Initial energy (E_0)	0.5 J
Free space model	10 pJ/bit/m^4
Data aggregation (E_{DA})	5 nJ/bit
Number of rounds	2500
Sink position	(50 m, 50 m)

5.1 Average Number of Dead Nodes

It indicates the number of nodes drained or died up to the current round. Fig. 5 illustrates the number of dead nodes with respect to the number of rounds. It is observed that the node starts to die in EACR-LEACH is slower than LEACH and SE-LEACH. In addition, it is noted that the number of nodes dead in LEACH, SE-LEACH and EACR-LEACH is 100, 98 and 95 respectively, for the network round of 2000. Thus, the number of nodes dies in EACR-LEACH is slowly compared than LEACH and SE-LEACH. The reason is that the metrics of RER, Distances, NoN, and NTNACH, are considered.

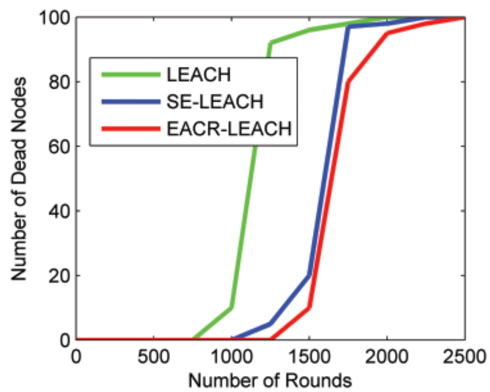

Figure 5: Number of dead node *vs.* number of rounds

Tab. 2 shows number of dead nodes with respect to the number of rounds. It is observed that the node starts to die in EACR-LEACH is slower than LEACH and SE-LEACH. Thus, the number of nodes dies in EACR-LEACH is slowly compared than LEACH and SE-LEACH. The reason is that the metrics of RER, Distances, NoN, and NTNACH, are considered.

Table 2: Number of dead node *vs.* Number of rounds

Number of rounds	LEACH	SE-LEACH	EACR-LEACH
0	0	0	0
250	0	0	0
500	0	0	0
750	0	0	0
1000	10	0	0
1250	92	5	0
1500	96	20	10
1750	98	97	80
2000	100	98	95
2250	100	100	98
2500	100	100	100

5.2 Average Residual Energy

The network lifetime completely depends on the operations such sensing, transmitting, receiving and aggregation. If the network nodes consume more energy in each round, the lifetime of networks drain early. Fig. 6 illustrates the average residual energy or average network energy concerning number of rounds. It is observed that average residual in LEACH, SE-LEACH and EACR-LEACH is 2, 5 and 10 J respectively, for the 2000th round. It is noted that the proposed EACR-LEACH consumes 5% lesser than SE-LEACH and 10% lesser than LEACH. It's because the CH selection parameter, particularly NTNACH, is taken into account. As a result, the battery slowly depletes.

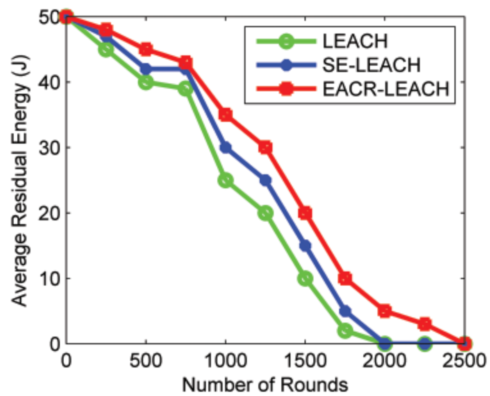

Figure 6: Average residual energy *vs.* number of rounds

Tab. 3 illustrates the average residual energy or average network energy concerning number of rounds. It is noted that the proposed EACR-LEACH consumes 5% lesser than SE-LEACH and 10% lesser than LEACH. It's because the CH selection parameter, particularly NTNACH, is taken into account. As a result, the battery slowly depletes.

Table 3: Average residual energy (J) *vs.* number of rounds

Number of rounds	LEACH	SE-LEACH	EACR-LEACH
0	50	50	50
250	45	47	48
500	40	42	45
750	39	42	43
1000	25	30	35
1250	20	25	30
1500	10	15	20
1750	2	5	10
2000	0	0	5
2250	0	0	3
2500	0	0	0

5.3 Average Throughput

It shows how many data packets the sink has successfully received from nodes. Fig. 7 illustrates the number of packets sent to the sink in terms of rounds. It is observed that number of packets sent to the sink in LEACH, SE-LEACH and EACR-LEACH is 10000, 11500 and 13000 respectively for the 2500th round. It is noted that number of packets sent in EACR-LEACH increases by 16% and 24% respectively compared to SE-LEACH and LEACH. It's because the CH selection parameter, particularly NTNACH, is taken into account. Thus, it increases the number of packets between the participant and the sink.

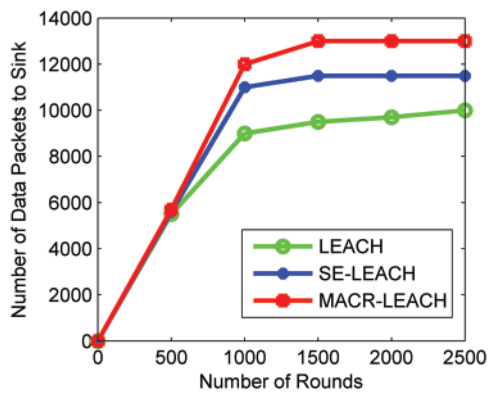

Figure 7: Number of packet sent to the sink *vs.* number of rounds

Tab. 4 illustrates the number of packets sent to the sink in terms of rounds. It is noted that number of packets sent in EACR-LEACH increases by 16% and 24% respectively compared to SE-LEACH and LEACH.

Table 4: Number of packet sent to the sink *vs.* number of rounds

Number of rounds	LEACH	SE-LEACH	EACR-LEACH
0	0	0	0
500	5500	5600	5700
1000	9000	11000	12000
1500	9500	11500	13000
2000	9700	11500	13000
2500	10000	11500	13000

6 Conclusion and Future Work

In Internet of Things (IoT), energy conservation is a challenging task, as the devices are made up of low-cost and low-power sensing devices and local processing. This paper proposed the Energy-Aware Cluster-based Routing (EACR-LEACH) protocol in WSN based IoT. The Cluster Head (CH) selection is a crucial task in clustering protocol. In EACR-LEACH, the CH is selected by using the routing metrics, Residual Energy (RER), Number of Neighbors (NoN), Distance between Sensor Node and Sink (Distance) and Number of Time Node Act as CH(NTNACH). The simulation is conducted on MATLAB 2019a. The accomplishment of EACR-LEACH is compared to LEACH and SE-LEACH. The proposed EACR-LEACH network lifespan is increased by 4–8%, while throughput is increased by 16–24%.

In the future, we would like to deploy the EACR-LEACH protocol in real-time and include the appropriate routing metrics to strengthen data security when transferring data from cluster member to base station. Finally, the performance of EACR-LEACH is compared to LEACH and SE-LEACH.

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