An Energy Efficient and Balanced Clustering Approach for Improving Network Performance in Wireless Internet-of-Thing's Sensor Networks Application

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***Abstract:-* The Wireless Internet-of-Thing's Sensor Networks is used in various control systems, including environmental monitoring, home automation, oil industry and chemical/biological attack detection. The Wireless Sensor Network (WSN) is a collection of sensor and routing nodes which may be put together to predict physical conditions in the environment. Despite the numerous advantages of such technology, the depleting of sensor battery capacity is a major worry, owing to the substantial computing and communication tasks performed by individual sensors. However, WSNs are frequently deployed in remote areas where human intervention for post-deployment maintenance is not possible. Therefore, efforts are being made to improve their efficiency and durability. The majority of the research has focused on energy consumption, which is one of the most critical design considerations in WSN enabled IoT systems. Clustering strategy is one of the most efficient methods for power conservation in such an energy-constrained network. This paper proposes a new variant of LEACH protocol named Resilient Routing Algorithm (RR-LEACH). The proposed algorithm selects the appropriate CH, rotates the nodes uniformly, and gradually depletes the cluster nodes' energy. According to the simulation results, the RR-LEACH algorithm outperformed other conventional solutions in terms of network lifetime and performance. Most importantly, RR-LEACH will considerably increase the sensor's lifetime, making this manner of deployment more practical in IoT applications.**

Keywords: Internet of Things, Wireless Sensor Networks, Resilient Routing Algorithm, Energy efficiency, Network performance.

1. INTRODUCTION

Recently the Internet of Things (IoT) has become the most interesting technologies due to the diverse applications such as smart phones, military, health care monitoring, disaster management, and other surveillance systems [1]. Fig.1 depicts the Internet of Things' generic architecture. The IoT incorporates sensing, connectivity, networking, and cloud computing into these control sectors. Wireless Sensor Networks (WSNs) are widely used in a wide range of IoT applications. Recent advancements make it easier for people to go about their regular lives. Smart devices in IoT-assisted WSN applications are connected to the Internet through a device known as a Base Station (BS) or gateway router. There are several types of users who are interested in obtaining the data of relevant IoT devices like, doctors, industrialists, and smart home users. Therefore, the IoT enables for real-time access about any device, leading in increased productivity and efficiency [2].

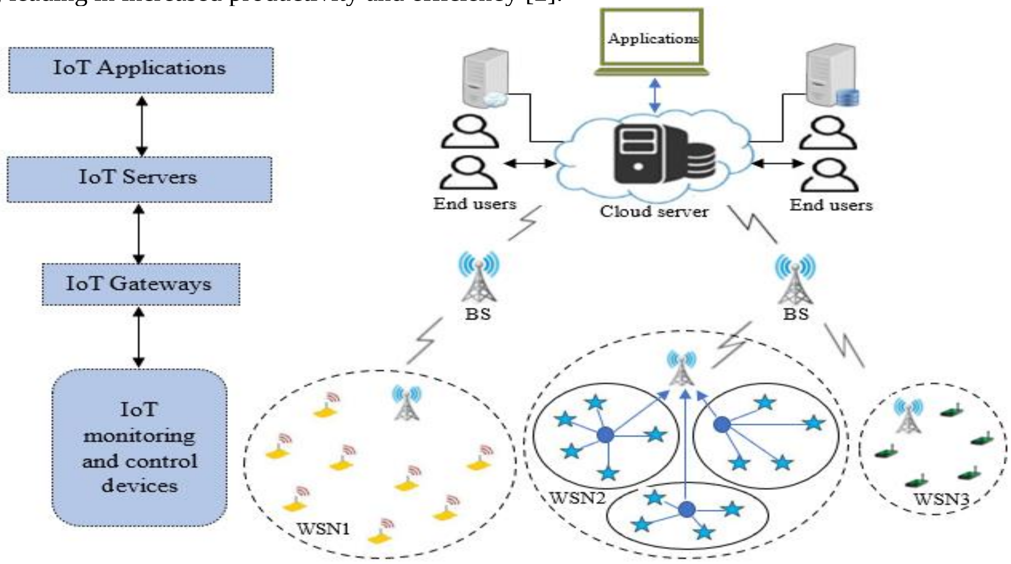

Fig.1. Generic Internet of Things architecture

The WSN is a network that connects the virtual and physical worlds. Wireless sensor nodes are in charge of sensing and transmitting data to the Internet. Wireless sensor nodes are used to monitor a variety of physical and environmental parameters in a network field. Since the sensor battery is not always rechargeable, the data routing strategy from the sensing node to the BS should be energy efficient [3].

Unlike an ad-hoc network, a WSN designed for IoT applications faces a variety of challenges, including the number of sensor nodes, hardware, communication mode, battery and computational cost. In addition to data detection, sensors used in the IoT paradigm are given extra functionality, and they must deal with new concerns such as Quality of Service (QoS), security, and power management [4-5]. Some of these difficulties are solved by implementing various technological enhancements in the WSN's primitive protocols and schemes. Resilient routing algorithm, data redundancy, dynamic network size, less reliable medium, heterogeneous network, and multiple BS all provide substantial problems to QoS requirements in IoT-based WSNs. The fundamental goal of WSN routing is to identify the most energy-efficient path and transmit data from sensor nodes to the BS in order to extend the network's lifetime.

Clustering is one of the most efficient methods for reducing the energy consumption and increasing the network lifetime [6]. The clustering technique creates a hierarchical structure of clusters or groups of sensing nodes that collect and transmit data to the Cluster Head (CH). Sensed data are combined by the CH and sent to the BS. LEACH is a traditional clustering algorithm that takes energy into account when routing data hierarchically. The network is organized into clusters, and each sensor node delivers data to the appropriate CH. For each round, the LEACH protocol selects CHs at randomly in a stochastic manner. The CH connects to each cluster member node to collect the sensed data. Time Division Multiple Access (TDMA) schedules are assigned by the CH to each cluster member. The Member Cluster (MC) can transfer data during the selected time period. The data must be verified and compressed before interacting with the BS.

Choosing a CH is tough since numerous parameters must be considered while selecting the optimal node in the cluster [7]. The routing mechanism considers the distance between nodes, residual energy, mobility, and throughput of each node. The LEACH algorithm improves the network's lifetime for direct and multi-hop transmission, although it still has a number of drawbacks CHs are randomly picked, thus proper distribution and an optimum solution cannot be guaranteed. During CH selection, nodes with lower energy levels have the same priority that those with higher energy levels. As a result, when a low-energy node is chosen to serve as a CH, it dies out rapidly, resulting in a shorter network lifetime.

In this paper, we introduce a new routing protocol that is suited for IoT-based WSN applications. The suggested approach is based on the clustering topology and selects the optimal CH, rotates the nodes uniformly, and gradually depletes the cluster nodes' energy based on the conventional LEACH protocol. The following is the main contribution of our work in this paper:

- To improve the network performance, we present a resilient routing algorithm for WSNs enabled IoT applications. The proposed algorithm aims to decrease the homogeneous sensor node energy consumption, improves the network lifetime, and enhances the balance of the load in the network.
- The clustering threshold method is used during the selection and formation of CHs. CH is selected based on residual energy, current round energy, and the optimal CH value.
- The clustering method must be used repeatedly in each round. CHs are selected using the dynamic threshold. It may result in the completion of a significant number of CHs and the clustering of each cluster member.

The remaining part of the paper is organized as follows: Section 2 describes the basic background and related work. In section 3, LEACH's Background and Overview are explained in detail. In Section 4, we discuss our suggested system model and algorithm. The proposed RR-LEACH method of clustering is mentioned in Section 5. Section 6 presents the simulation results and analyses. Finally, the paper is concluded in Section 7.

2. RELATED WORK

Although routing algorithms are a well-established research subject, clustered protocols for WSNs-IoT systems present a distinct number of design challenges. Clustering algorithms related to WSN for IoT applications are classified in two categories: (i) multi-hop clustering, and (ii) single-hop clustering.

Multi-hop clustering is a type of radio network communication in which the network coverage area exceeds the radio range of individual nodes. Therefore, a sensor node can use other sensor nodes as relays to reach the BS. Due to energy constraints within WSN nodes, many studies related to multi-hop routing algorithms have been considered in order to reduce energy consumption and increase network lifetime. LEACH is one of the most often used algorithms in this field [8]. The LEACH protocol has undergone multiple revisions, resulting in a wide range of WSN routing strategies [9].

Vida et *al*. [10] suggested an Energy Efficient Cluster Head Selection in Internet of Things. Using Minimum Spanning Tree (EEMST). The proposed method uses graph theory to select the optimal CH and data routing for a multi-hop IoT applications. On the basis of a weighted network, this algorithm calculates the Euclidean distance-based minimal spanning tree. The EEMST algorithm extends the network's lifetime by limiting the quick draining of the node battery. However, the EEMST algorithm presents significant drawbacks when used in a network with a relatively high density.

Moreover, the Multi-hop routing with LEACH (MR-LEACH) is one of the LEACH developments that uses equal clustering topology [11]. Using the MR-LEACH algorithm, the network is divided into multiple cluster levels. The CHs in each layer cooperate with the adjacent layers to transfer data to the BS. Other nodes join CHs, based on the Received Signal Strength Indicator (RSSI). The BS chooses upper-layer CHs to serve as super CHs for lower-layer CHs. The BS is also in charge of determining the TDMA schedule for each CH to transmit the sensed data.

Furthermore, one of the LEACH advancements is PEGASIS protocol, which employs a chain of nodes to start data transmission from the farthest node, that each node sending its data to the closest neighbor [12]. This method balances energy consumption inside a chain, however it results in higher data transmission delays, making it unsuitable for large networks.

Despite the multi-hop routing algorithms are energy efficient for the IoT-based WSNs applications, single-hop routing algorithms presents a well-established research field. Nitin Kumar et *al*. [13] present an Energy-Efficient Advanced LEACH Clustering Protocols in Heterogeneous and Homogeneous WSNs in order to improve the balance of energy consumption among different parts of the sensor network. Using this approach, the LEACH algorithm is improved in two ways: ADV-LEACH1 and ADV-LEACH2. The ADV-LEACH1 takes into account the nodes' residual energy as well as the long-distance node's factors. The data fusion rate is then implemented, allowing CHs to fuse data before sending it to the BS. To become CHs, the distance between the sensor nodes and the BS should be lessened, so that the CH node consumes less energy and fewer CHs die. Sensor nodes will not communicate if they are too far away from the BS and CHs. The ADV-LEACH2 focused on resolving this issue. The second strategy uses a new nodes distribution mechanism, such as Gaussian distribution, to get rid of some sensor nodes that were far away from the BS and CHs. Using this method, the sensor nodes' heterogeneous deployment has been rescheduled, balancing the nodes to cover almost the same distance.

Node's energy conservation as well as the temperature balance and workload of IoT devices was also recognized by Praveen et *al*. [14]. In their study, the authors combine the Moth Flame Optimization (MFO) and Ant Lion Optimization (ALO) algorithms. The CH selection models which are investigated in this work are distance and energy, delay, load, and temperature. Target nodes must be within a specific distance of the CH when using the distance constrained selection strategy. The same holds true for energy restricted choices in terms of energy discharging in IoT networks. Based on the hybrid approach, the proposed algorithm provides an energy-efficient routing WSN-IoT network.

In the similar setting, Praveen et *al*. [15] present the self-adaptive whale optimization algorithm (WOA). The proposed algorithm is intended for smart IoT applications. In the IoT Network, energy consumption, distance and latency of nodes, as well as temperature and load of nodes, have all been considered as important aspects. The most important factor to consider here is choosing a node as CH with the highest energy and the shortest distance. This method attempted to balance the system's energy consumption thereby extending the network lifetime. The authors of [16] presented the Residual Energy Based Cluster-head Selection in WSN for IoT Application (R-LEACH), in response to the same challenges. The proposed algorithm analyzes the higher energy consumption and rotates the CH position between nodes. The initial and residual energy of each node, as well as an appropriate number of CHs, are all taken into account in this strategy. The remaining energy of non-CH devices is evaluated in the final round. As a result, the node with a higher energy consumption is given priority in selecting the CH in the following round. The modified CH selection method enhances network performance in terms of residual energy, packets sent to BS, throughput, and network lifetime.

To avoid the CH overload during cluster formation many researchers have come up with the idea of Fuzzy Logic (FL), which is applied in wireless Internet-of-Things sensor networks for decision making [17]. Other related works improve network performance and prolong network lifetime by examining the mobility of sensor nodes. Popovic et *al*. [18] propose the idea of mobile, solar-powered CHs that relocate themselves inside clusters in such a way that the total energy consumption in the network is reduced and the network lifetime is extended.

To maintain IoT standards updated, researchers have focused on device energy-saving approaches like as clustering algorithm, where the CH should be carefully selected. Clustered routing protocols have proved its ability to achieve energy efficiency in all of these approaches, motivating the authors to continue their study in this area.

3. LEACH'S BACKGROUND AND OVERVIEW

LEACH is a basic single-hop clustering procedure that saves a lot of energy when compared to non-clustering approaches [19]. Sensor nodes are grouped to form clusters after they've been installed. Each cluster uses a CH for data aggregation. The protocol is analyzed in each round. CHs are chosen randomly and clusters are generated in real time. CMs have an equal chance of being elected as CH in order to balance energy dissipation. The BS checks the residual energy on a regular basis until the lifetime is over. The steps involved in each round of the LEACH protocol are depicted in the flowchart illustrated in Fig. 2.

Each node generates a number at random between the intervals [0,1]. If the number will be less than the T(sni) threshold value specified by equation (2), the node will become a CH in each round.

$$T(sni) = \begin{cases} \frac{P}{1-P*\left(r*mod\left(\frac{1}{P}\right)\right)}, if\ n\ \in\ G, \\ 0, \qquad Otherwise \end{cases} \tag{1}$$

The CH rotates for each round based on the electing probability, implying that all nodes in the cluster, regardless of residual energy, have the same chance of being elected as a CH. During the CH election process, it is possible to elect a CH with little residual energy, which will die out quickly as compared to one with a higher energy level. Therefore, the residual energy of each node, as well as the energy of each round, are included into the CH selection probability equation. As a result, nodes with higher energy levels are more likely to become CH. If the elected CH's round energy exceeds the residual energy, the related CH will remain as a CH.

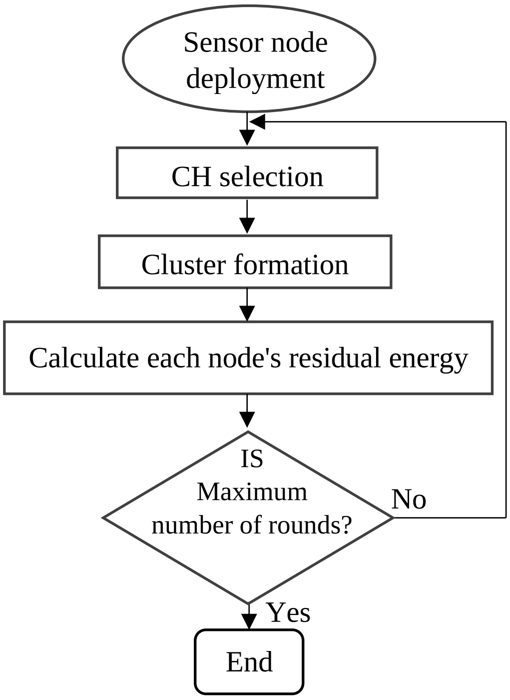

Fig. 2. Flowchart of LEACH protocol.

4. SYSTEM MODEL

In recent years, the rapid development in urban population density has necessitated modern infrastructures with sufficient services to meet the needs of QoSs. Therefore, recent advancements in wireless communication technologies, such as WSN-assisted IoT, have been in great demand for smart cities development [20]. The goal of this paper fits into this context. The wireless sensor nodes are grouped in four distinct rooms to form clusters, as shown in Fig.3. Let's pretend that each cluster has seven sensor nodes, but only one of them can be a CH at any given time. The BS collects data from each cluster and transmits the fused information to the end user.

The appropriate routing is required for environment-monitoring applications so that network energy can be used effectively [21]. Data transmission from a correspondent cluster will be halted if a node with lesser residual energy is chosen as CH. Therefore, the end user will be unable to access all of the information required to monitor environmental conditions.

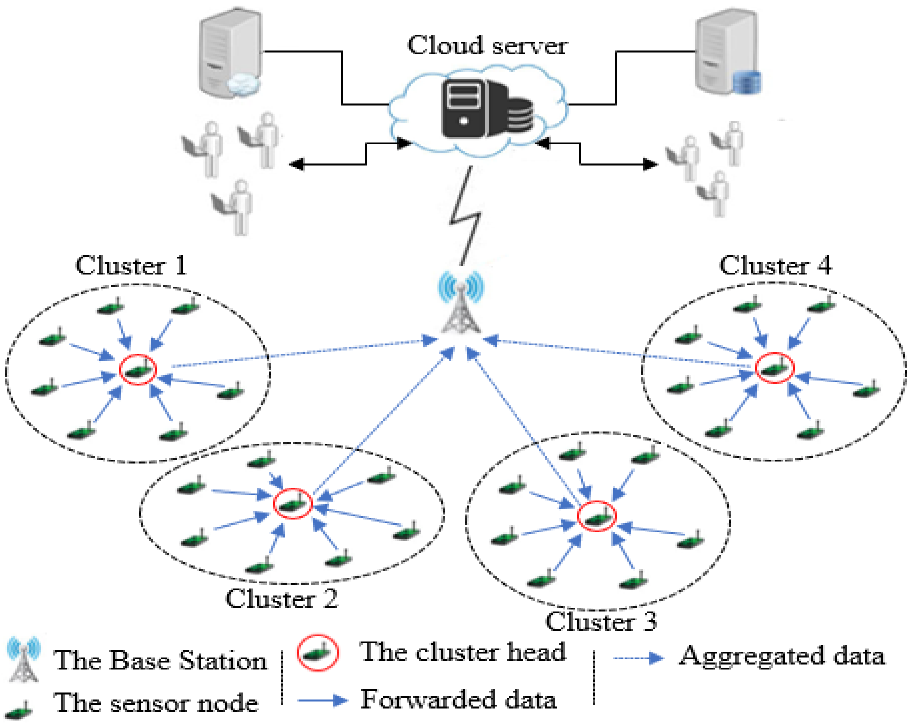

Fig.3. IoT-based environmental monitoring.

The communication model shown in Fig. 4 was considered to analyze the behavior of the proposed model. The free-space model is used for short-distance communication, such as between MCs and CHs within the cluster. For longer-distance communication, such as between CHs and the BS, the multi-path fading model is adopted. Based on the energy dissipation model presented in [22], the following equations can be used to calculate the amount of energy required to send and receive l-bit packets:

$$E_{Tx}(l,d) = \begin{cases} E_{elec} \times l + \varepsilon_{fs} \times d^2; & d \leq d_0 \\ E_{elec} \times l + \varepsilon_{mp} \times d^4; & d > d_0 \end{cases} \quad (2)$$

$$E_{Rx}(l) = E_{elec} \times l$$

Some appropriate assumptions for the suggested system model are as follows:

- Nodes are static and homogeneous.
- The BS is permanently placed in the center of the network.
- Nodes are randomly distributed and send data on a regular basis.
- Each cluster has a CH that communicates with the BS using the single-hop or multi-hop communication according to the specified application.

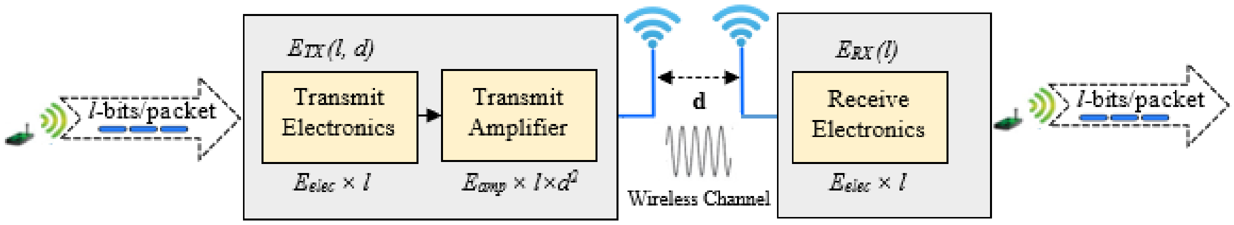

Fig. 4. Radio energy model.

The notations used in the manuscript to analyze the used parameters are summarized in Table 1.

Table 1. Summary of the used notations.

Notation	Meaning
CH	Cluster Head
CM	Cluster Member
BS	Base Station
n	Total number of wireless sensor nodes
l	Length of message in Bits
p	Probability to select a node as CH
T(sni)	Threshold function value against i^{th} sensor node
DT	Direct Transmission
TDMA	Time Division Multiple Access
$E_{res}^{r_i}$	Remaining energy level of the node during the i^{th} round
$E_{round}^{r_i}$	Energy will be consumed by the elected CH during the i^{th} round
E_0	Initial assigned energy level
M	Network diameter
m	Number of clusters
K	Optimal number of CHs
ϵ_{fs}	Transmitter amplifier refers to the free space mode
ϵ_{mp}	Transmitter amplifier refers to the multi-path attenuation mode

Table 1. (Continued).

Notation	Meaning
$E_{processing}$	Energy consumption in local processing
E_{Tx}	Transmitter Electronics
E_{Rx}	Receiver Electronics
E_{elec}	Energy consumption of transmitting l-bit
$d_0 = \sqrt{\epsilon_{fs}/\epsilon_{mp}}$	Critical value for dividing the spatial model.
DRN	Death Rate of Nodes
FND	First Node Dead

HND	Half Nodes Dead
LND	Last Nodes Dead
SRE	System Residual Energy
MST	Minimum Spanning Tree

5. THE PROPOSED RR-LEACH

The proposed approach is intended to solve the LEACH algorithm's as well as direct transmission's restrictions. The RR-LEACH algorithm is based on the LEACH classification technique, which is one of the most widely used. The proposed method uses the CH and the BS with a single-hop communication. The RR- LEACH algorithm aims to enhance the balance of the load in the network using appropriate cluster head selection algorithm. As depicted in Fig.5, the CH election is based on the residual energy and the current round's energy.

The proposed protocol is a two-stage hierarchical clustering technique that includes setup and steady-state stages. During the initial setup phase, sensor nodes were grouped into clusters. In each cluster, a CH was in charge of gathering data from MCs. The data is fused within the corresponding CH to conserve space by removing redundant bits. The actual data routing occurs during the steady-state stage, when the network's CHs forward the collected data to the BS.

The clusters and CHs are formed in the first round of the setup stage using the conventional LEACH method. Each node in the network dissipates a certain amount of energy during data transport, which varies from node to node. The quantity of energy expended is related to the distance between the sending and receiving nodes. Therefore, for the next round, the CH selection is checked using a modified equation as follows:

$$T(sni) = \begin{cases} \alpha * \left(\frac{p}{1 - p\left(r \bmod \frac{1}{p}\right)}\right) * (1-\beta) * K_{opt}; if\ n\ \in\ G \\ 0;\ Otherwise \end{cases} \quad (3)$$

Where;

$$\alpha = \frac{E_{res}^{r_i}}{E_0}\ and\ \beta = \frac{E_{round}^{r_i}}{E_{res}}$$

The optimal number of clusters k_{opt} can be written as [23].

$$K_{opt} = \frac{\sqrt{n}}{2\pi}\sqrt{\frac{E_{fs}}{E_{amp}d^4(2m-1)E_0 - mE_{DA}}}\ M \quad (4)$$

The residual energy for each CH is determined using the following equation:

$$E_{res}(\text{CH}) = E_0(\text{CH}) - (E_{Tx}(\text{CH}) + E_{Rx}(\text{CH}) + E_{processing}(CH)) \quad (5)$$

Each member cluster node transmits a l-bits message to the CH during each round, resulting in the total energy wasted in the network during a round being described as:

$$E_{round} = KE_{cluster} = l(2nE_{elec} + nE_{DA} + k\varepsilon_{mp}d_{toBS}^4 + n\varepsilon_{fs}d_{toCH}^2) \quad (6)$$

The residual energy of the chosen CH is examined during each round after selecting the upper energy node as a CH. The selected CH will continue as a CH if the remaining energy is greater than the current round's energy; otherwise, it will be assigned as a MC. This would save the network from being too exhausted too quickly.

For i=1, $\frac{E_{round}^{r_1}}{E_{res}}$ is set to 0 because there is no need to consider the round energy in the first round. As a result, just simple LEACH is used in this round. For the subsequent rounds, the number of rounds $r_i\ \forall_{i \in \{1,\ldots,max\}}$ increases, β increases, and (1 - β) decreases, balancing the weight between the percentage and residual energy required to select CHs. The suggested model incorporates the clustering concept as well as periodic energy level assessments in each round, resulting in increased network reliability. Therefore, this protocol can not only extend the network lifetime, but can also balance energy between sensor nodes.

Once the CHs for the current round have been chosen, they send information about their CH announcements to MCs in their clusters. The sensing nodes evaluate the request message's signal strength before deciding which CHs to join. To avoid data collisions, the CH broadcasts the Time Division Multiple Access (TDMA) schedules for the member nodes to send data in different time slots. The process is repeated for the remaining rounds until all of the nodes in the network have been using up all of their energy.

Data is transmitted to CHs during the steady-state stage during the time slot allocated to each node. The CH will begin processing the data after all of the nodes in the cluster have finished sending data. The CH receives data, then aggregates it to remove redundancy and compresses it as much as possible to improve the bandwidth utilization. According to the specified application, the data is subsequently sent to the BS via single-hop or multi-hop transmission. The advantages of the suggested algorithm compared with other methods are summarized in Table 2.

Table.2. Comparison of clustered routing protocols in WSN-assisted IoT.

Algorithm	CH selection parameters	Advantages	Disadvantages
LEACH	- CH selection is randomly, regardless of the nodes' remaining energy.	- Energy load distribution on network sensors. - Avoiding the battery's quick depletion.	- Ignore the node's remaining energy in the CH selection process. - All nodes, including those with lower energy, have the same chance to become CH.
PEGASIS		- Reducing the clustering overhead using a chain technique. - Decreasing the power consumption. - Increasing the network's throughput.	- Not recommended for High density networks.
ADV-LEACH1	- Distance between the sensor nodes to the BS. - Initial energy as well as the residual energy of sensor nodes.	- Balancing the energy consumption. - Improving the network stability.	- Sensor nodes located far from BS and CHs are unable to connect. - The cluster with a large number of members is overburdened.
ADV-LEACH2	- The 2D elliptical Gaussian distribution method. - Distance between the sensor nodes to the BS. - Initial energy as well as the residual energy of sensor nodes.	- Enhancing the network lifetime. - Balancing the energy consumption.	- Low-energy nodes that are too far away from the BS will never become CHs.

Table 2. (Continued).

Algorithm	CH selection parameters	Advantages	Disadvantages
Hybrid	- The WSN's delay, distance, and total energy. -Temperature as well as the load of IoT devices.	- Increasing the network lifetime. -Enhanced CH selection efficiency among IoT devices. - Balancing the load and temperature of IoT devices	-The number of alive nodes, total energy of alive nodes, and node distances to alive nodes are not taken into account during the CH selection process.
SAWOA	- Sensor node energy, distance, and delay in a WSN. - IoT device load and temperature.	- Improving the network's lifetime by balancing the number of alive nodes and the network's normalized energy.	- More energy consumption.
EEMST	- The node's residual energy. - The total energy of alive nodes in clusters. - Total distances between living nodes and their neighbors in the MST. - Distance between nodes and the Base Station. - The MST's number of node neighbors. - Number of active nodes in the cluster.	- Extending the network's lifetime. - Avoid the quick depletion of node batteries.	- Not recommended for high density network.
R-LEACH	- Initial energy as well as the residual energy of individual nodes. - The network's optimal number of CHs.	- Increase the network's lifetime. - Reduce the energy consumption.	- The number of alive nodes in the cluster as well as the total energy are not taken into account.
RR-LEACH	- Initial energy. - Residual energy of the individual node. - Optimal number of CHs in the network.	- Significantly increasing the network lifetime by reducing the total energy consumption effectively. - Optimizing the network throughput. - Enhancing the network stability. - Enhance the load balance in the network. - Build a more resilient routing environment.	- Not recommended for network with low initial energy nodes. - Not considering the distributed routing table.

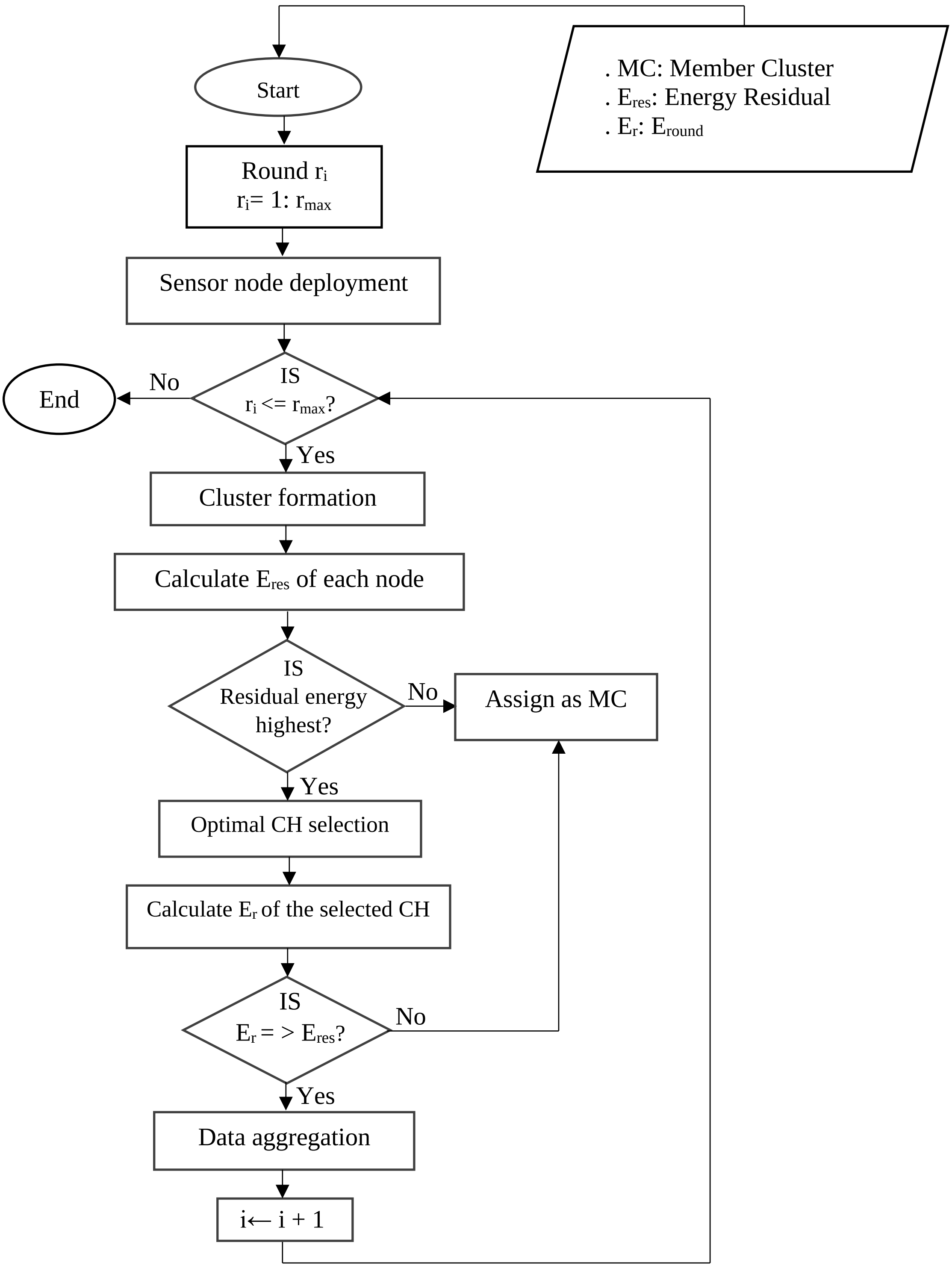

Fig. 5. Flowchart of RR-LEACH protocol.

6. SIMULATION RESULTS AND DISCUSSION

To evaluate the proposed RR-LEACH protocol, two simulations were done using MATLAB version R2013a. The first simulation was done with 200-sensor nodes scattered randomly across a (100×100) m^2 network as shown in Fig. 6(a), while the second simulation was done with 100-sensor nodes scattered randomly across a (100×100) m^2 network as shown in Fig. 6(b). The simulation parameters are similar to those used in numerous point-of-care studies on this topic. The network lifetime, Network stability, the NDR Node Death Rate (NDR), Average Residual Energy and the packets received by the BS are the most commonly used performance metrics to assess the performance of the proposed method. The NDR is measured by determining the First Node Death rate (FND), Half of Nodes Death rate (HND), 75% of Nodes Death rate and Last of Nodes Death rate (LND).

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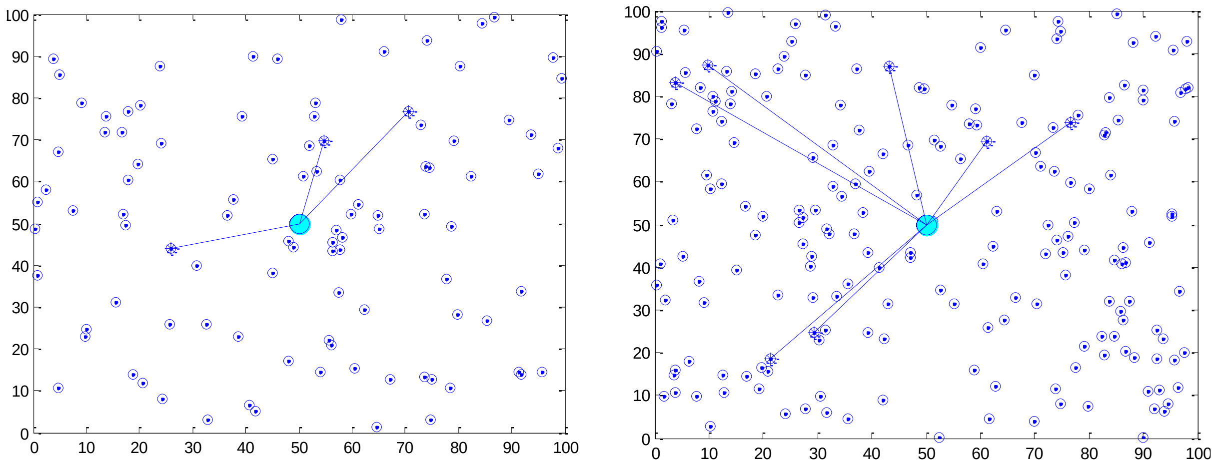
Table 3. Simulation parameters of sensor network.

Parameters	Value: First simulation 200-sensor nodes	Value: second simulation 100-sensor nodes
Initial Energy of each node (E_0)	0.6J	0.25J, 0.75J, 1.0J
Data Packet Length (Bits)	4000	2000
Sensing Area	(100×100) m^2	
Energy dissipation: receiving (E_{amp})	0.0013 pj/bit/m^4	
Energy dissipation: free space model (E_{fs})	10 pj/bit/m^2	
Energy dissipation: power amplifier (E_{amp})	100 pj/bit/m^2	
Energy dissipation: aggregation (E_{DA})	5 nJ/bit	



(a) (b)

Fig.6. The experiment environment at round 1500: (a) 100 sensor nodes in (100×100) m^2 WSN; (b) 200 sensor nodes in (100×100) m^2 WSN.

6.1. Network performance analysis

In this section, 200 sensor nodes are deployed in a (100 × 100) m^2 area. The original energy for all sensor nodes was 0.6J. We adopt a packet size of 2000 bits to make a fair comparison with the compared approaches.

6.1.1. The Network Lifetime analysis

The simulation result in Figs.7 and 8 shows the achieved network lifetime and NDR by, LEACH ADV-LEACH1, ADV-LEACH2 and RR-LEACH. The current clustering algorithm's main contribution is to improve network lifetime according to LND metrics. Fig.8 depicts performance differences between the approaches based on the number of dead nodes per round. In comparison to LEACH, ADV-LEACH1, and ADV-LEACH2, RR-LEACH has a substantially lower rate of dead sensor nodes. The suggested RR-LEACH algorithm has a significantly higher node survival rate than LEACH, ADV-LEACH1, and ADVLEACH2. The network lifetime based on LND 3500, 2415, 2552, 22872, and 2401 belongs to RR-LEACH, LEACH, ADV-LEACH1, and ADV-LEACH2, respectively. Therefore, RR-LEACH is energy-efficient and capable of extending the network lifetime approach.

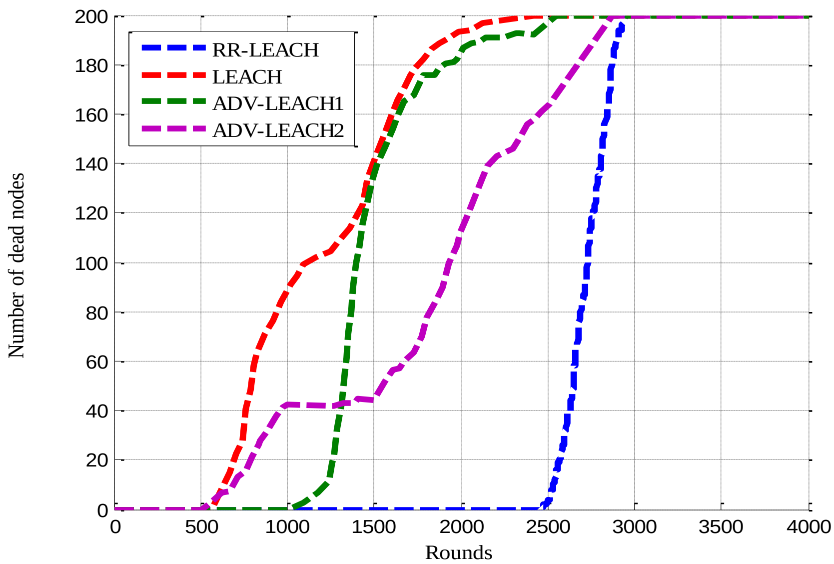


Fig.7. The network lifetime.

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Given that FDN or even some percentage of the dead nodes for high-density IoT enabled WSN applications give considerable attention as the estimated value for the average of the lifetime and performance of the network, Fig.8 illustrates performance contrasts between the approaches based on the HND and 75% ND. We conclude from this result; the proposed algorithm outperforms all other examined protocols in terms of network performance. Therefore, the proposed RR-LEACH is more efficient than LEACH, ADV-LEACH1, and ADV-LEACH2 by 59%, 49%, and 29%, respectively regarding HND. Either in terms of 75% ND, RR-LEACH also outperforms LEACH, ADV-LEACH1, and ADV-LEACH2 by 46%, 43%, and 18% respectively.

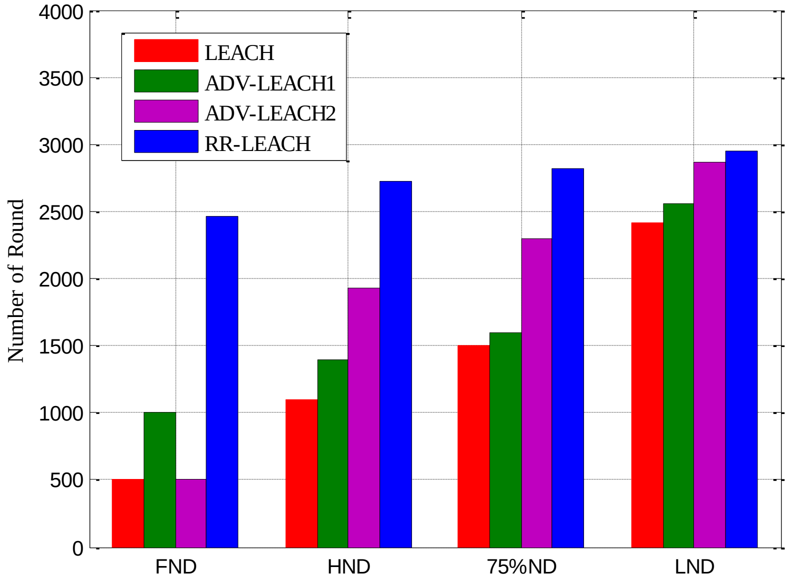

Fig. 8. NDR evolution during the network lifetime.

Since the LEACH protocol assumes that CHs expend the same amount of energy for each round, inefficient CH selection occurs, thus reducing the network's lifetime. The RR-LEACH selects CHs based on the residual energy of nodes, energy required to affect the current round, and an optimal number of clusters, allowing the network lifetime to last longer.

6.1.2. The System Residual Energy analysis

Nodes are outfitted with a limited power source in many IoT applications. Therefore, the nodes' energy should be used efficiently to ensure network's long-term sustainability. The influence of the System Residual Energy (SRE) on network performance appears to be important for further analysis of this protocol's effectiveness. The SRE and energy consumption evaluation of LEACH, ADV-LEACH1, ADV-LEACH2 and RR-LEACH are presented in Figs. 9 and 10. As shown in the plotted results, the RR-LEACH is much more than the other three algorithms. LEACH selects CHs using its own probability function, in which each node has the same chance of becoming a CH, resulting in all nodes dying fast due to the blind CH selection strategy. Due to its CH selection technique that maximizes the network's energy efficiency, the proposed RR-LEACH exhibits a slower decrease as the number of rounds increase as compared to other existing techniques. Since the energy for RR-LEACH depletes slowly, the network lifetime can be extended to a greater number of rounds.

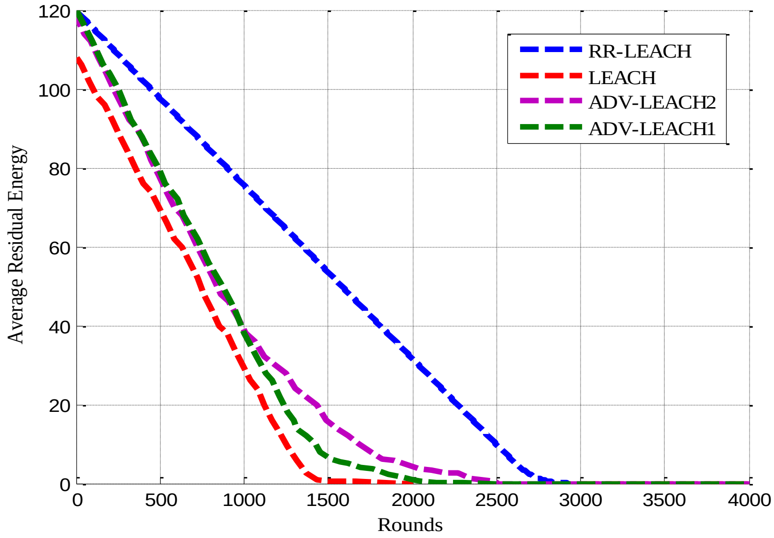

Fig. 9. Average residual energy comparison

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As shown in Fig. 10, LEACH consumes more energy in fewer rounds. LEACH consumed 90% of the total power after 1200 rounds, while ADV-LEACH1 and ADV-LEACH2 consume 90% of total power after 1370 and 1620 rounds, respectively. To consume 90% of total power, 2450 rounds are required for RR-LEACH protocol. Therefore, the RR-LEACH accomplish less energy consumption as compared to other existing up to 90%, 50% and 10% of SRE.

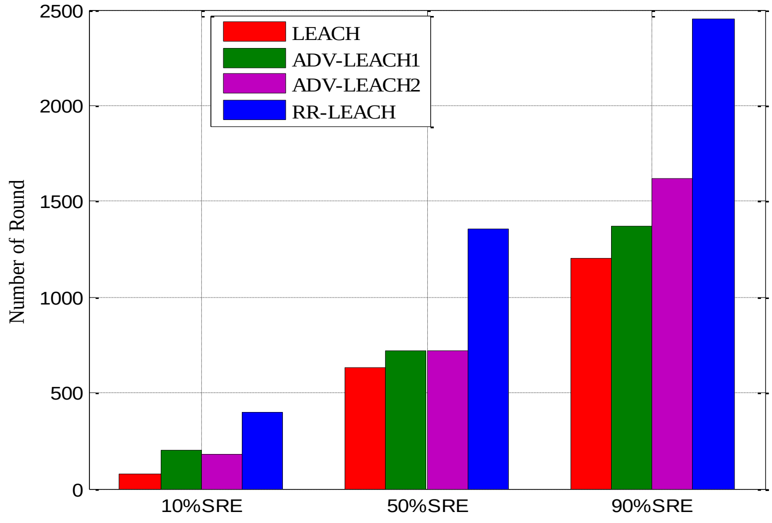

Fig.10. Energy consumption evolution

6.1.3. Number of Packets Received analysis

For IoT applications, the amount of data delivered to the BS is a critical factor. The rate of accuracy of the nodes is defined by the amount of packet received by the BS, which is referred to as throughput. The greater the amount of data obtained, the higher the accuracy. The total number of packets received versus the number of rounds is depicted in Fig.11. As we can see, from the first to 500th round, all four algorithms have approximately comparable values. After the 500th round, LEACH sends much fewer messages to the BS than other techniques. The RR-LEACH generates significantly more total received statements than LEACH, ADV-LEACH1, and ADV-LEACH2. The RR-LEACH packet delivery gradually increases, due to complete connection and an alternate routing method between sensor nodes.

Since the CHs are selected and maintained as a CH based on their residual energies, it effectively guarantees a good network throughput in terms of packets reaching to BS and a proper appropriate operation. The improved performance of network throughput is due to the resilient mechanism of CHs selection. Unlike other systems that do not consider important elements like residual energy and the energy of each round. The suggested framework includes an effective threshold value for selecting CHs, which improves packet delivery ratio in smart IoT-based WSNs applications.

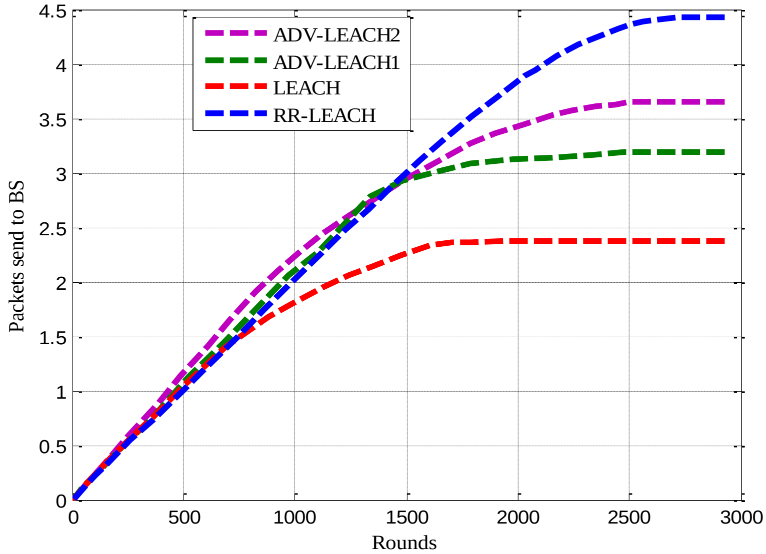

Fig. 11. Packets received by the BS.

6.2. Impact of original energy on network performance

Network Stability and Network Lifetime are two critical parameters for ensuring good network performance in IoT-based WSNs applications. The time interval between the start of network operation and the death of the first node (FND) is known as network

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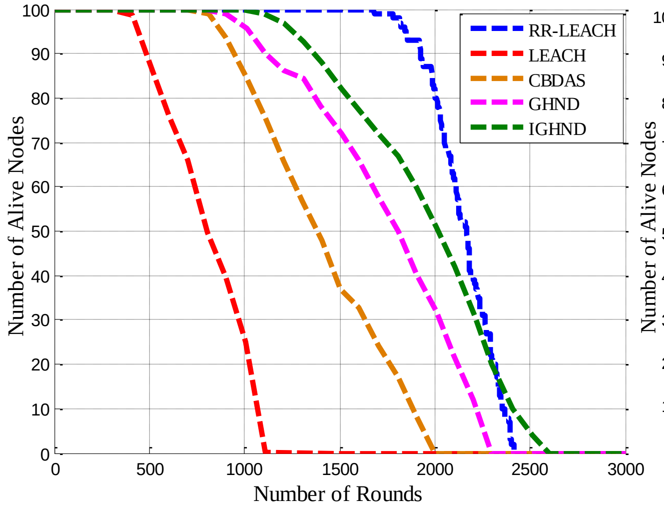
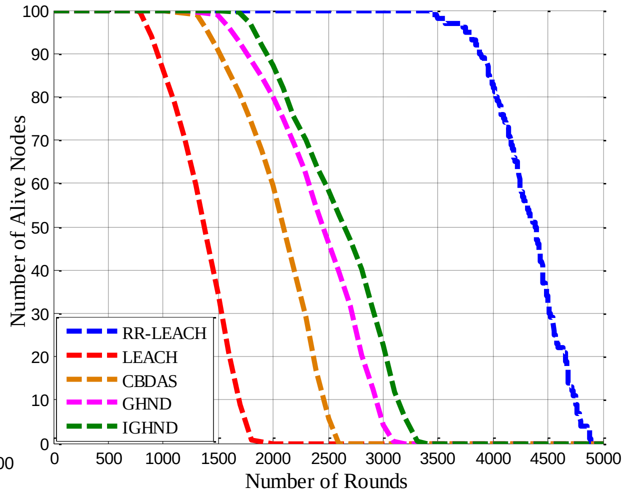
stability. To study the behavior of the proposed RR-LEACH protocol, we analyze and evaluate the network stability and overall network lifetime. For a fair comparison with methodologies proposed for WSN enabled IoT applications, such as IGHND [24], GHND [25], and CBDAS [26], we adopt a packet size of 2000 bits. The systems are simulated for 100 sensor nodes in a (100×100) m^2 area. Network permanence's are measured in terms of number of rounds by considering different initial energy of 0.25J, 0.5J and 1.0J.

Given that the network lifetime is defined as the time from the beginning of the network till the death of the Last node (LND). As illustrated in Fig. 12, the proposed algorithm is compared to existing protocols in terms of network lifetime by taking into account different initial energies of 0.25J, 0.5J, and 1.0J. Both IGHND and RR-LEACH perform similarly at 0.25J starting energy, however there is a significant difference at 0.5J and 1J, for the following reasons. Eq. (3) is proposed by the product of two terms, including the percentage, the remaining energy ratio with different coefficients α and $(1-\beta)$ and the number of optimal CHs. When E_0 is low, α and $(1-\beta)$ reduce quickly during the network lifetime. Therefore, the CH selection decision's balance is less important. For quite high initial energies, the proposed algorithm proved to work well.

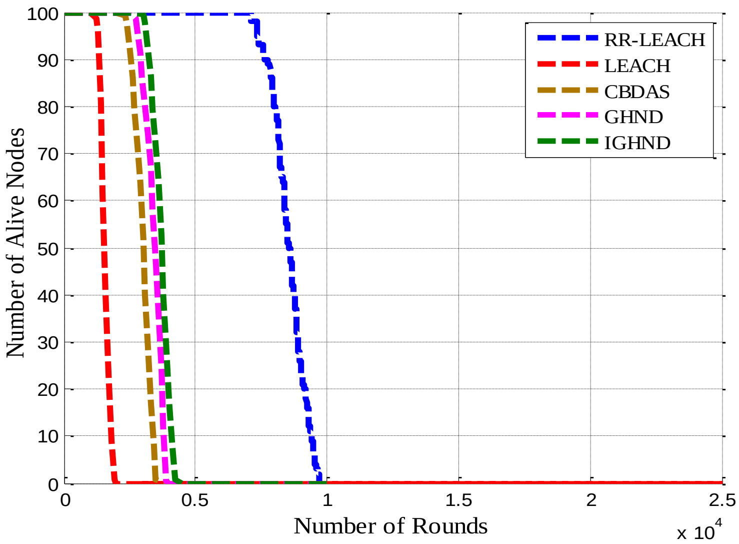
For an initial energy of 0.5J, the RR-LEACH, IGHND, GHND, CBDAS, and LEACH protocols have network lifetime of 4887, 3400, 3200, 2600, and 2000 rounds, respectively. Considering the initial energy of 1J, 100% depletion of sensor nodes occurs after about 9700 rounds in RR-LEACH. For IGHND, GHND, CBDAS, and LEACH these values are 4500, 4000, 3500, and 2000 respectively. Therefore, using 0.5J, the suggested RR-LEACH algorithm extends network lifetime by 30.42%, 34.5%, 46.79%, and 59%, over the IGHND, GHND, CBDAS, and LEACH algorithms, respectively. Applying 1.0J, the proposed algorithm has better performance in IoT applications with the advantage of boosting the wireless network lifetime by 53.6%, 58.76%, 63.91% and 79.38%, compared to IGHND, GHND, CBDAS, and LEACH, respectively.



(a) Initial energy of 0.25J



(b) Initial energy of 0.5J



(c) Initial energy of 1.0J

Fig. 12. The achieved lifetime for varying initial energy: Number of alive nodes vs. number of rounds. Energy initial of (a) 0.25J; (b) 0.5J; (c) 1.0J.

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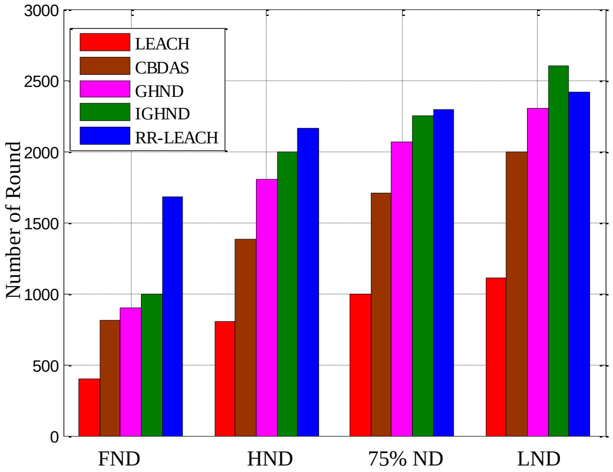
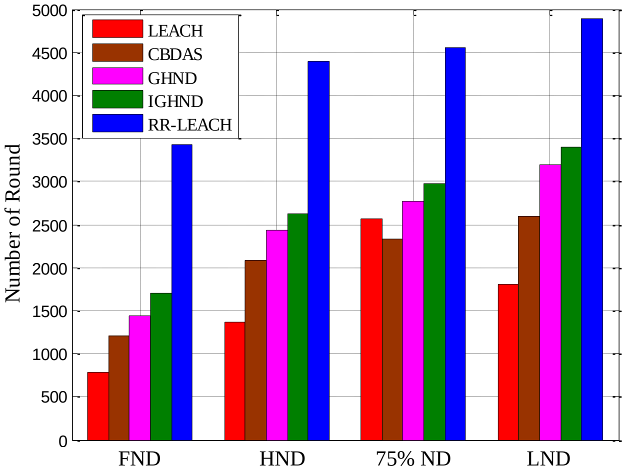
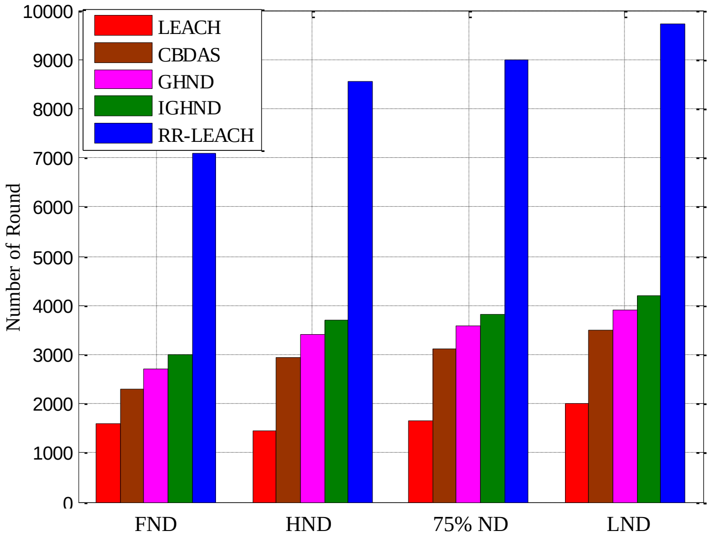
According to NDR evolution during the network lifetime shown in Fig. 13, the network stability of RR-LEACH outperforms LEACH, CBDAS, GHND and IGHND by 76.19%, 51.84%, 46.42% and 40.47% respectively for an initial energy of 0.25J. Considering 0.5J, the RR-LEACH algorithm is 77.19%, 64.91%, 57.9%, and 50.29%, superior to LEACH, CBDAS, GHND, and IGHND algorithms respectively. For 1.0J the proposed RR-LEACH algorithm improves the network stability by 85%, 67.6%, 62%, and 57.75% than the LEACH, CBDAS, GHND, and IGHND algorithms, respectively. Furthermore, the proposed RR-LEACH method outperformed all other algorithms in terms of the death of the half node (HND) in various energy levels.



(a) Initial Energy of 0.25J



(b) Initial Energy of 0.5J



(c) Initial Energy of 1.0J

Fig. 13. NDR evolution during the network lifetime under varying initial energy. Initial energy of (a) 0.25J, (b) 0.5J, (c) 1.0J.

7. CONCLUSION

A resilient routing algorithm known as RR-LEACH was proposed in this paper to make WSNs more sustainable and optimize their operation in a range of smart IoT applications. The suggested protocol was aimed to address the constraints of LEACH by introducing the clustered routing protocol based on residual energy and regular round energy evaluation. According to the results of the performance analyses, RR-LEACH outperforms, LEACH, ADV-LEACH1, ADV-LEACH2, CBDAS, GHND and IGHND, in terms of network lifetime, network stability, node death rate speed, and residual energy depletion speed, as well as traffic load generated on the network. As a result, the network performance has improved in contrast with different existing approaches.

We intend to expand our work in the future by developing the adaptive neural networks to investigate any further benefits of the suggested approach.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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