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A Secure LEACH Protocol for Efficient CH Selection and Secure Data Communication in WSNs

Ravi Kumar Sanapala
Department of Electronics and Communication Engineering, Jawaharlal Nehru Technological University, Hyderabad, Telangana, India
E-mail: ravi430us@gmail.com

Srineevasa Rao Duggirala
Department of Electronics and Communication Engineering, Jawaharlal Nehru Technological University, Hyderabad, Telangana, India

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Abstract: Due to the applications of wireless sensor networks (WSNs) in distinct fields, like civilian and military, environmental monitoring, and target tracking, etc., it became the important research area for researchers. Therefore, an efficient organization of network topology is needed for multi-hop data aggregation based on the energy constrained WSNs with large scale deployment for making the routing task simpler, balancing the load efficiently, and enhancing the network lifetime. The low-energy adaptive clustering hierarchy (LEACH) is an architecture of application-specific protocol, which is used for WSNs. However, this LEACH protocol suffered from more energy consumption in network without considering the cluster heads (CHs) distribution on a rotation basis. In addition, the complex security mechanisms are not sufficient due to limited bandwidth and other restrictions that the sensor nodes have. Thus, it is essential to improve the energy efficiency, CH stability and secure data transmission in WSN's, which is the main objective of this work. Motivated from these three challenges, this article proposes a stable and secure LEACH (SS-LEACH), in which a new and improved protocol of LEACH is proposed for enhancing the stability of CH and energy efficiency as it considers the nodes' consumed energy ratio (CER) for CH selection and random number generation, here after the proposed LEACH is named as CER-LEACH. In addition, it aims to prevent the previously elected CH node and it will get another chance in the current round. This method correlates the threshold used in traditional LEACH with the energy consumption ratio of each node. Further, it also introduces a hybrid reputation-based data transmission (HRDT) scheme for secure data transmission. With the proposed CER-LEACH protocol, WSNs achieves better performance in terms of secured communication, network lifetime, and energy consumption based on the analysis of simulation results as compared to state-of-art approaches.

Index Terms: LEACH Protocol, Secure Communication, Cluster Head, Consumed Energy Ratio, Hybrid Reputation-Based Data Transmission, Energy Dissipation.

1. Introduction

In the networking field, one of the most popular and widely used technologies is the WSNs as it has a wide range of applications [1]. WSNs include numerous tiny sensor nodes, which are powered by battery devices and deployed over the network for collection of useful data and transmit it to SINK nodes via wireless links [2]. The communication of sensor nodes is being either with other nodes or SINK directly. The major challenge that has been faced by WSNs is that they have limited energy resources [3]. The energy consumption, network lifetime and network operations are relied on the clustering, robust self-organization, and routing protocols [4]. Due to the limited computational resources and buffering features of WSNs, some drawbacks have been presented [5]. Because of three activities, such as communications, data processing, and sensing, energy consumption is occurred at sensor nodes [6]. The significant part of the wireless device's consumed energy is constituted in the communication energy. The optimization of energy is focused on the operating modes of radio module. The definition of communication energy is described as the summation of data processing and data transmission energies (i.e., transceiver energy) [7]. To enhance the sensor nodes' lifetime and ensure the network availability and connectivity, the network should be operated with optimal energies. As WSNs have limited energy sources, energy optimization requires for minimizing the energy consumption of sensor nodes and prolonging the network lifetime [8]. It necessitates to consider the energy efficiency as an important aspect

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for network designing and operations for communication between sensor nodes and overall network. The approaches like cluster formation and different communication modes of data transmission have become more popular in recent decades [9]. The traditional architecture of clustered network is depicted as shown in the Fig. 1.

The sensor nodes' energy can be used efficiently by using the cluster-based routing protocols than the non-clustering protocols [10]. In this routing method, a cluster leader, known as the CH, plays a crucial role in the elimination of correlated data that can be reduced the final data volume. The aggregated data will be transmitted by the CH to the BS [11]. The sensor nodes categorize into different clusters in the cluster-based routing protocols for reducing the energy consumption and workload balancing that causes due to the energy consumption difference between nodes and CHs [12]. The clustering is the efficient technique to achieve the improved energy efficiency and prolonged network lifetime. The optimal selection of CHs is performed in many clustering methods that could be avoided the sensor nodes' premature death and ensures the prolonged network lifetime [13].

In WSNs, the major concern would be the security, including data security, data integrity, and protection from different internal and external attacks in addition to the challenge of energy efficiency [14]. The protocol that has been used for management of energy consumption can't be handled the security issues. For protecting the nodes data against external attacks, a lot of conventional secure techniques are existed [15]. But the new complex security methods have not been suited for WSNs owing to the limited bandwidth and minimum size of nodes [16].

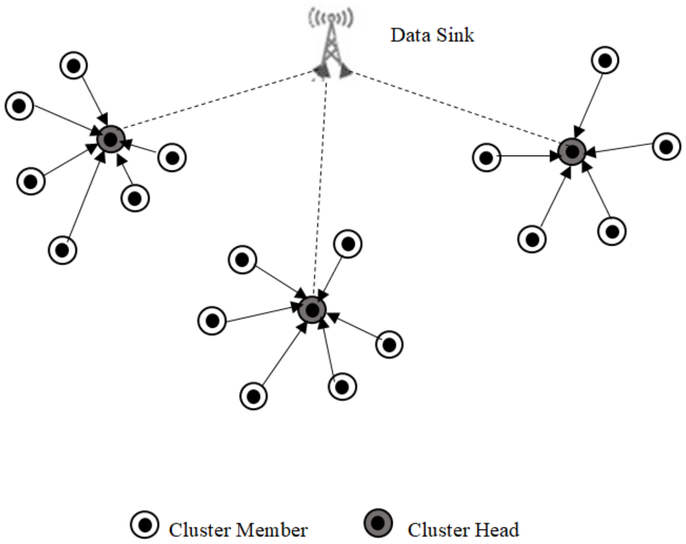

Fig.1. Network topology of a clustered WSN.

1.1. Contributions in this Paper

- The random number generation and threshold is correlated with CER of the sensor nodes to balance the energy consumption & prolong the network lifetime.
- The CHs selected in the previous round is not selected as CH in the next round, because its CER is very high as compared to non CH nodes.
- It prevents the previously elected CHs node will get another chance in the current round.
- The HRDT method ensures a secure transmission of data among the sensor nodes by selecting the relay nodes based on the proposed hybrid node reputation model.
- The proposed method calculates QoS reputation rate based on node energy & link quality. It improves the overall packet delivery ratio by allowing only the nodes with sufficient energy & link quality for data forwarding.

2. Literature Survey

When designing a WSN, the major issue is considered as the energy consumption. Based on the battery life of sensor nodes, the network lifespan would be resulted. One of the strategies is the clustering that can be increased the network lifetime. Different methods have been introduced for secured data transmission.

In [17], the authors have proposed DFCR for unequal clustering mechanism to minimize the cluster's size that are nearer to the BS and resolve the WSNs' hotspot issue. Santhosh V. Purkar et al., [18] have proposed a novel solution for designing the energy-efficient clustering method for HWSN. The CH selection is considered in the clustering based on different parameters, like residual energy, initial energy, and hot count. The proposed method improves HWSN protocol's energy efficiency, lifetime, stability, and throughput compared to the other methods, like SEP, DEEC, and LEACH. Seyed Mostafa Bozorgi et al., [19] have proposed a hybrid unequal energy-efficient clustering and layered multi-hop routing for WSNs. Based on the information about neighbour nodes in the clustering, the protocol strategy is determined, and layering is performed. With the elimination of excess control messages, energy consumption and network overhead are reduced. The simulation results prove that the proposed HEEC method achieves the improved stability than the FHRP, LEACH-ERE, EADUC-II, and HUCL.

Salil Bharany et al., [20] have presented a methodology for an energy-efficient clustering method for data collection and transmission using the optimized protocol of LEACH. The energy utilization is diminished by the proposed method for data transmission. The better performance results are achieved using the proposed method in terms of packet delivery ratio and energy efficiency than the existing LEACH protocols. Sadia Firdous et al., [21] have proposed a clustering-based routing method for optimization of energy resources with the consideration of load balancing. The cluster-head rotation and distance calculation have been managed the energy utilization at sensor nodes. The simulation results display that the proposed method provides the improved performance by 60% of average energy consumption and network lifetime compared to the LEACH algorithm. Salim El Khediri et al., [22] have introduced the layered arrangement and a load balancing method between CHs for management of data packets. The network is partitioned into unequal sizes for data packets routing among sensor nodes. The proposed protocol provides quite improved performance in terms of energy consumption, network lifetime, and reliability. Anshu Kumar Dwivedi et al., [23] have demonstrated the balanced energy dissipation to overcome the hotspots in WSNs. The authors have been discussed the cluster formation and CH selection based on fuzzy inference systems. Experimental results were proved that the proposed method EE-LEACH delivers better performance compared to the earlier protocols like DFCR and SCHFTL.

2.1. LEACH Protocol

To prolong the network lifetime and achieve the scalable solutions, the LEACH protocol has been considered as the primary clustering-based routing protocol, which minimizes the utilization of global energy through the continuous distribution of load among all nodes across different points. The hierarchical organization of sensor nodes is included in the clusters, each of which has a CH. However, CH is used to collect the data from all nodes, aggregate it, and route the data towards the SINK node. LEACH elects the node as CH if it has a probability that defines by the chosen random number between 0 and 1 and should be lower than the particular threshold $TH(n)$ (Eq. 1). In a certain cluster, the remaining nodes are joined based on the CH selection that can be reached using the least communication energy. For preventing the single sensor node's battery draining, the CH role is rotated among all nodes.

$$TH(n) = \begin{cases} \frac{P}{1-P\left[\left(r \bmod \frac{1}{P}\right)\right]}, & if\ n\ \in G \\ 0, & otherwise \end{cases} \quad (1)$$

Where, P refers to the probability value and $TH(n)$ represents the nodes' threshold value. In the network, a random number from 0 to 1 is chosen by each node.

Two different rounds are involved in the LEACH operation that initiating with the setup phase for organization of nodes into clusters and is followed by using a steady-state phase, in which data transmission is responsible from source to SINK nodes. By comparing with the setup phase, the steady-state phase is longer for overhead minimization. After deciding a node as a CH during the setup phase, the advertisement message is broadcasted. To be joined in a certain CH, each non-cluster node will be decided based on the message reception. The data transmit by each member node in the steady-state phase while aggregating the received data from different nodes inside the cluster using CH and sending towards the SINK. The control information from the SINK is not needed for LEACH and knowledge about the global network doesn't require for nodes.

The network lifetime prolonging is allowed in the LEACH protocol. To enhance the effectiveness of new LEACH-based protocols, some weaknesses have been addressed. Some of the problems and their solutions have been mentioned as follows:

- There is an assumption of all sensor nodes can reach towards the SINK in LEACH that affecting the scalability. It could be addressed using the multi-hop routing and multi-level clusters.
- The energy inefficiency could be caused due to the involved overhead and changes in CH. This issue can be resolved with the reduced number of rounds in the phase of cluster rebuilding.
- The remaining energy of sensor nodes doesn't be considered when determining the probability of chosen CHs. The faster energy loss could be caused at nodes when they have lower remaining energy that might be chosen as CHs. It results in the disconnecting the entire cluster.
- The fluctuation of number of CHs is performed heavily that results in the unbalanced cluster partitions. It leads to the increased energy consumption of the network.

In this paper, a novel improved energy-efficient SS-LEACH protocol has been proposed to overcome the disadvantages of traditional techniques and prolong the network lifetime. The proposed method correlates the threshold used in traditional LEACH with the energy consumption ratio of each node to prevent the previously elected CH node will get another chance in the current round.

3. Proposed Method

3.1. CH Selection Using CER-LEACH

In the conventional LEACH protocol, the process of CH selection is initiated with the generation of random number by the nodes. Then, this generated random number is matched with the threshold. The node would become CH for a round when its random value is much smaller compared to the threshold. The CH's current residual energy can't be ensured even though different advantages are there in the LEACH protocol. The traditional LEACH-based protocols have been involved the threshold selection $TH(n)$ that consider only about the selection of nodes as the CH irrespective their energy levels. It may result in the earlier death of CHs when nodes that have lower energy are selected CHs.

To overcome all these restrictions, a new CH selection procedure is proposed that includes the complete selection procedure of CH based on the sensor nodes' CER. The overall system performance is increased that will enhance the network lifespan. The traditional process of random number generation in the LEACH protocol is modified in the proposed CER-LEACH protocol, where the random number multiplies with the ratio of nodes' energy consumption to the initial energy of nodes. In the traditional LEACH, the used threshold correlates with the node's energy consumption ratio in this technique. The mathematical formulation of CER is expressed as follows Eq. (2):

$$CER = \frac{E_{initial} - E_{res}}{r-1} \tag{2}$$

Where, E_{res} refers to the residual energy, $E_{initial}$ indicates the initial energy, and r is the current round. In the next round, the CH selection will be performed using the CER of previous round. The node that has the lowest value of CER in the previous round has been chosen as CH for next round. It's important to make a note that the CH of previous round wouldn't be continued as CH anymore in the next round because that node has higher CER than the non-CH nodes.

Based on the nodes' energy, the random numbers have been generated because of the consumed energy ratio with multiplicative effects. Additionally, the process of CH election is relied significantly on the random numbers' generation. The proposed random number generation is represented as follows Eq. (3):

$$rand(n_{new}) = rand(n) * CER \tag{3}$$

$$rand(n_{new}) = rand(n) * \frac{E_{initial} - E_{res}}{r-1}$$

Where, $rand(n)$ is the normal random number. By comparing with the sensor nodes' threshold values, the improved random number values have been computed. According to the nodes' probability values, the CH is selected using the threshold function, where the nodes' energy levels can be used efficiently that ensures the network performance. The proposed CER-LEACH protocol's threshold function is represented as follows Eq. (4):

$$TH(n) = \begin{cases} \frac{P_n}{1-P_n\left[\left(r \bmod \frac{1}{P_n}\right)\right]} * CER + \frac{r}{P_n}, & if\ n \in G \\ 0, & otherwise \end{cases} \tag{4}$$

Where, P_n refers to the probability of sensor node n to become CH, ANE is the average node energy, and r indicates the round number.

To maintain the energy consumption uniformly, the CH role rotates among sensor nodes over the network. However, each node has an equal opportunity of being chosen as CH according to the selection probability. The energy of a node is determined to decide whether it is suitable for the CH role or node. Based on the CER value of previous round, the CH selection will be done for the next round, in which the node with the lower CER of previous round will be selected as CH. Due to the higher CER of a node that was played a CH role in the previous round, it wouldn't be elected as CH in the next round. The threshold function matches with the modified random number value $rand(n_{new}) \leq TH(n)$. The node would become CH when the random value is smaller than threshold. Otherwise, the process of CH selection would be restarted for the next node.

There is an additional energy requirement for the CH node compared to others in the cluster. Nodes with low energy levels will die soon if they are chosen as CH in the primary round. It will affect the network lifespan and system performance. The energy of a node should be considered in the threshold function during the selection of CH among sensor nodes. If in case CH distributes uniformly among nodes, the sensor network can be continued operated for a longer time. CH selection probabilities are used to determine the threshold function for all the nodes. In the determination of proposed CER-LEACH protocol's threshold function, the nodes' energy levels have been utilized until the end of a network.

Once the election of CHs is completed based CER, the CHs will inform the other nodes of the information that they became CH in this round. In the form of broadcast message, an advertisement message will be sent to all other nodes by each CH node. The decision of whether each member node should participate in the cluster formation is made based on the signal intensity of broadcast message that transmits to the BS from each CH node.

3.2. Secure Data Transmission Using HRDT

The network is secured from both unknown and known attacks using the efficient methodology. For that, the network divides into clusters, where the CH is elected by each cluster. The sensed data send to CH using the member nodes while it aggregates and transmits to the BS. Here, the traffic flow of a network is many to one. Some attacks could be undergone by malicious nodes within a network. Each node is responsible for monitoring and establishing the mutual trust with the neighbouring nodes in addition to the sensing. This paper proposes a HRDT for secure data transmission. In HRDT, the reputation for the sensor nodes is calculated using the following reputations:

i. Community reputation rate – given by neighbour nodes
ii. QoS reputation rate – calculated by node QoS

By combining these reputations, the composed reputation score of the sensor nodes is evaluated. This reputation rate determines the reliability & trustworthiness of the sensor nodes. The proposed HRDT scheme selects the forwarder nodes based on the calculated HRDT score. The node that has a higher score of HRDT will become a forwarder node among all nodes for the current round of communication.

Two different types of reputation rates have been evaluated using the proposed composite reputation-based routing protocol, such as QoS reputation and communication reputation. The nodes' energy and link are evaluated using the QoS reputation rate while the community reputation evaluates using the direct and indirect methodology.

Community reputation rate

Based on the number of unsuccessful or successful transitions of data between sensor nodes to CH or CHs within a particular interval for community reputation. In case of data packet transmission towards CH from sensor node within an interval, the successful delivery is achieved. Otherwise, it is unsuccessful delivery that represents the community reputation value's evaluation for sensor node. In two different ways, like indirect and direct reputation, the community reputation is computed using the proposed technique. Based on the one-hop or single-hop connected node, the direct reputation is determined using the HRDT. The multi-hop or one-hop nodes are used for indirect reputation.

To determine the directly connected nodes' value, the CH of respective clusters has been used during the estimation of direct reputation. However, the main aspect of direct reputation is the calculation of successful transitions of data packets for a particular interval from sensor node to CH, packet type, packet size, packet header, from CH or CH to CH, etc. Then, the indirect trust is evaluated using HRDT and transitive relation based on the same parameters, like packet type, packet header, number of successful transitions from CH to CH or sensor node to CH, packet size, etc. that don't correlate with CH directly. Below Eq. (5) is used to represent the community operation:

$$R_{com}(n) = w_1 DR_n(t) + w_2 \frac{IDR_n}{k}(t) \tag{5}$$

Where, $R_{com}(n)$ is community reputation of node n, DR_n is direct reputation of node n, IDR_n is indirect reputation of node n, t is time & w_1, w_2 are weight vector ranging from $0 \leq w_1, w_2 \leq 1$ & k is the number of neighbours respectively.

QoS reputation rate

To determine the QoS parameter, energy is the most crucial parameter that can be used to detect the malicious nodes that may use more energy than the other nodes because of malicious attacks and unnecessary storage.

For example, a very lower residual energy (E_{res}) will be there for malicious sensor node in comparison with the other nodes. It's essential to calculate QoS reputation of every sensor node to ensure the routing path free from the nodes doing malicious activities. In the proposed HRDT, the QoS reputation is calculated based on energy and link quality parameters:

QoS Energy**:** The sensor node's residual energy determines based on the difference between the initial energy & energy consumed so far for various activities such as data reception, transmission, computation, and malicious attacks when the node is a malicious type. The node's residual energy 'n' at time 't' is calculated as per the below Eq. (6)

$$E_{res}(n) = E_{initial}(n) - E_{con}(n) \tag{6}$$

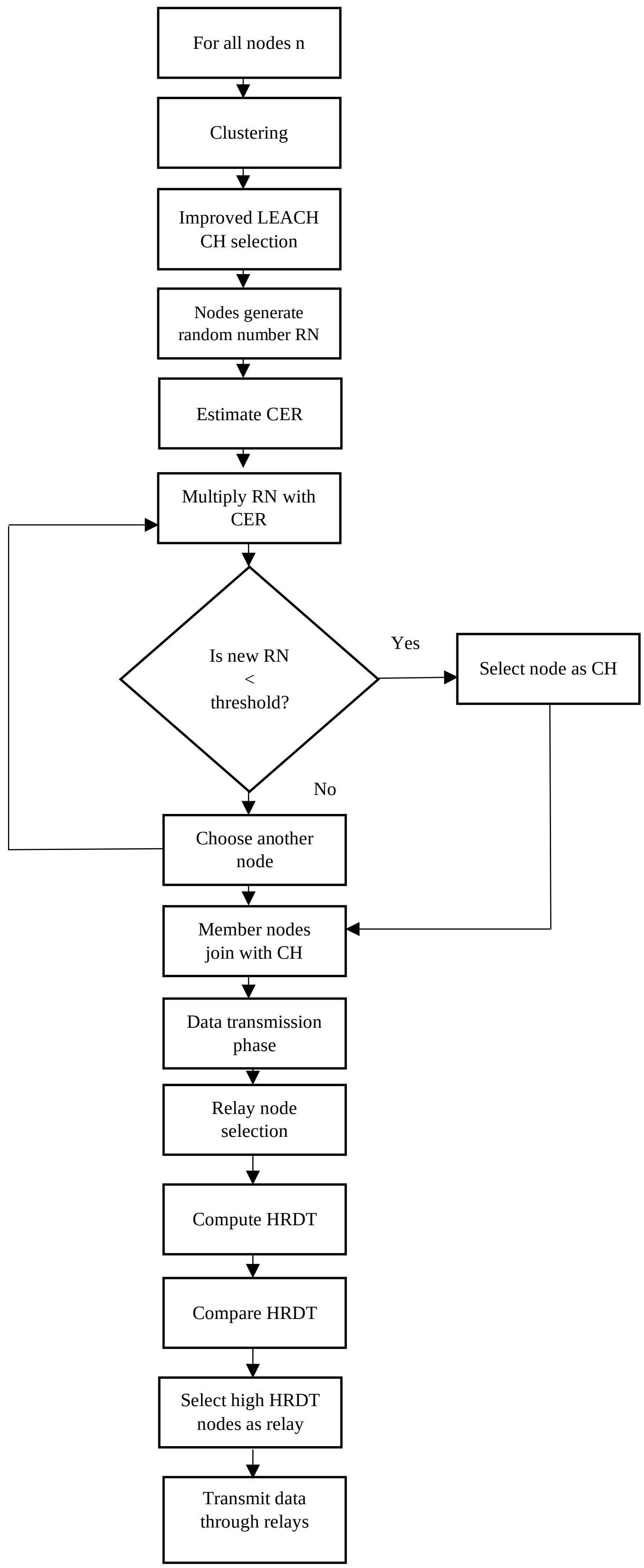

Fig.2. Flowchart of proposed system algorithm.

Where, $E_{initial}$ is the initial energy of node 'n' & E_{con} is the consumed energy. In general assumption, the malicious node holds the residual energy lesser than the Threshold value due to its abnormal activities. So, in QoS reputation model when the node's residual energy E_{res} is lesser than the threshold value, then the reputation is represented as per the below Eq. (7)

$$QoS_{energy}(t) = \begin{cases} 0, & if\ E_{res} < E_{th} \\ 1 - E_{con}, & else \end{cases} \quad (7)$$

***QoS link*:** It is determined by considering the received signal strength, link capacity and link quality. The signals are loss or attenuated if they propagate to the longer distance. Due to the environment or other different parameters like multipath propagation, it is also termed as propagation loss. With the use of link quality between nodes and current coordinates, the link quality can be estimates as follows Eq. (8):

$$QoS_{LQ} = \frac{1}{(1 - {R_n}/{Tx_n + 1})} \quad (8)$$

Here, LQ_n is indicates the node n's link quality, Tx_n refers to the node's maximum transmission range, and R_n is the node's radius.

The node's combined reputation is determined based on the community reputation & QoS reputation evaluations. The following Eq. (11) represents the hybrid reputation rate of node 'n'

$$TR = CR + QoS_R \quad (9)$$

$$TR_n = \alpha * R_{com}(n) + \beta * (QoS_{energy} + QoS_{LQ}) \quad (10)$$

$$TR_n(t) = \alpha * \left(w_1 DR_n(t) + w_2 \frac{IDR_n}{k}(t)\right) + \beta * \left(QoS_{energy}(t) + QoS_{LQ}(t)\right) \quad (11)$$

Where, TR_n is total reputation, $R_{com}(n)$ is community reputation rate of node 'n', QoS_{energy} & QoS_{LQ} are QoS reputation rate with respect to energy and link quality of node 'n' respectively. 't' is current time. α & β are constants and $\alpha + \beta = 1$ where $0 \leq \alpha, \beta \leq 1$.

Finally, the proposed HRDT scheme selects the forwarder nodes for the current round of communication based on estimated HRDT score and the node with high HRDT score will be selected as forwarder node for the current round of communication.

The proposed CH selection & secure data transmission is depicted and explained in the following flowchart (Fig. 2):

```
##
For all the nodes 'n' where n ∈ N
Divide the nodes as 'k' clusters
End for
CH selection
For all node 'n' where n ∈ k
Calculate CER_n
        Calculate TH(n)
        Estimate rand(n)
        rand (n_new) = rand(n) * CER_n
                If rand (n_new) ≤ TH(n)
                CH -> n;
                End if
End for
Data transmission
For all nodes 'n'
        Find TR = CR + QoS_R
        TR_n = α * R_com(n) + β * (QoS_energy + QoS_LQ)
                If TR(n) > TR(n + 1)
                RELAY → n;
                End if
End for
End
```

4. Result and Analysis

4.1. Simulation Setup

The proposed SS-LEACH is simulated, and performance is evaluated using NS2 and compare with SRN-LEACH [24], DEE approach [22], and EE-LEACH [23] mechanism. The random deployment of sensor nodes is included in the network field of $1000m \times 1000m$. All sensor nodes are set to the initial energy of 100j, and size of a network varies from 100 to 500 nodes. To generate the consistent traffic, the traffic agent of CBR is used during the transmission of data. The data communication is carried out by UDP. Below Table 1 shows the values of experimental parameters.

Table 1. The experimental parameters.

Parameter	Value
Network area	1000x1000
Number of nodes	100 to 500
Cluster size	8
Initial energy	100j
Packet size	1024
Routing protocol	AODV

4.2. Performance Evaluation

End-to-end delay is defined as the time taken for transmission of data packets over the network from source to destination. Table 2 shows the list of end-to-end delay values for a proposed technique. The stable CH selection and implementing CER along with random number reduces CH rotation.

Table 2. Comparison analysis of proposed with existing methods for delay.

Node	Proposed	SRN-LEACH [24]	EE-LEACH [23]	DEE [22]
100	0.016	0.020	0.023	0.039
200	0.017	0.021	0.024	0.038
300	0.016	0.020	0.025	0.042
400	0.018	0.021	0.024	0.045
500	0.017	0.021	0.025	0.048

Also, the relay selection using link quality & energy in QoS reputation model selects low overhead relays which assists in minimizing the end-to-end delay of a proposed method. In the network, the minimum average delay was reported as 0.016ms whereas the previous methods yield high delay up to 0.048ms compared to the proposed method. Fig. 3 represents the graphical view of end-to-end delay.

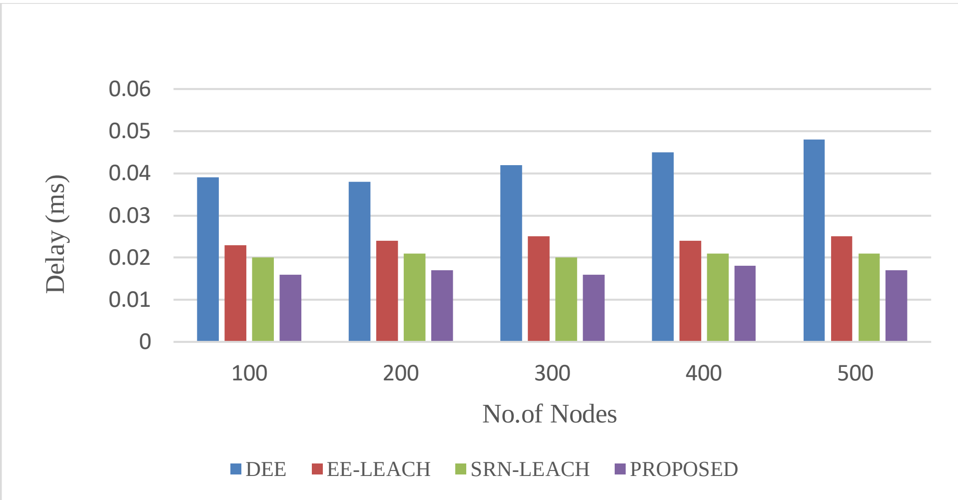

Fig.3. Graphical representation of end-to-end delay obtained using proposed and exiting methods.

To process the network activities, the sensor nodes integrate with the initial energy of 100j. During each activity of a network, the energy depletes that should be optimized to prolong the network lifetime. The CER is used to select the CHs and the relay nodes with the higher ratio of successful transaction have been chosen that eliminate the retransmission need and other energy consumption activities. Thus, the overall energy consumption will be reduced in the proposed network. The average energy consumption rate recorded in the proposed method was 4.2j. The simulation results are listed above Table 3. The graphical view of energy consumption shows in Fig. 4.

Table 3. Comparison analysis of proposed with existing methods for energy levels.

Node	Proposed	SRN-LEACH [24]	EE-LEACH [23]	DEE [22]
100	3.81	3.94	4.01	4.54
200	4.05	4.13	4.28	4.9
300	4.24	4.41	4.61	5.34
400	4.48	4.59	4.99	5.88
500	4.85	5.01	5.4	6.4

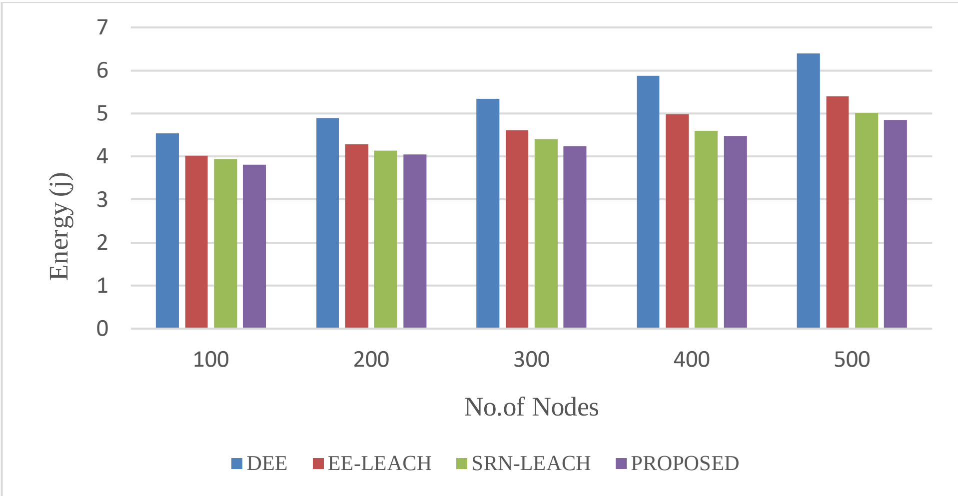

Fig.4. Comparison graph of energy consumption obtained using proposed and existing methods.

The lifetime of a network describes as the duration of performing the given activities in a network. In our work the network lifetime is related with the available energy of each sensor node after amount of time. The high remaining energy related to high network lifetime. Table 4 values proves that the proposed method improve the network lifetime to the great extent compared to the existing methods. The experimental results show in Fig. 5. PDR is the ratio between received data packets at the receiver and the sent data packets by the sender. The data aggregation through efficient relay selection improved delivery rate. The selection of stable & balanced CHs, and the optimal relay selection based on QoS reputation will be used to achieve the successful data forwarding by sensor nodes. The maximum PDR of 0.99% is achieved using the proposed technique while the average rate of 0.94 maintains with the existing techniques which is comparatively low PDR rate. The experimental results are listed above in Table 5 and as graphical in Fig. 6.

Table 4. Comparison analysis of proposed with existing methods for lifetime of network.

Node	Proposed	SRN-LEACH [24]	EE-LEACH [23]	DEE [22]
100	96.19	96.06	95.99	95.46
200	95.95	95.87	95.72	95.1
300	95.76	95.59	95.39	94.66
400	95.52	95.41	95.31	94.12
500	95.15	94.99	94.6	93.66

Throughput is another important parameter that determines based on the processing of a total number of data units using a node for a given period. The optimal data aggregation achieves with the implementation of energy constrained CH selection using CER and optimal relay selection based on link quality and energy in the QoS reputation. The higher throughput rate is achieved using a proposed technique than the previous methods. As shown in the above Table 6, the proposed method maintained the average throughput rate as up to 389kbps whereas the existing methods maintained low throughput rate than the proposed one. Fig. 7 represents the Network performance.

4.3. Discussion

The proposed CER-LEACH protocol outperformed the existing routing methods with respect to network performance metrics like end-to-end delay, energy consumption, lifetime of network, PDR, and throughput, as listed in

Table 2, Table 3, Table 4, Table 5, and Table 6, respectively. From the obtained simulation results the proposed CER-LEACH obtained 3.4%, 0.7%, and 0.13% increment in throughput, PDR, and lifetime. Further, it also reduced the energy, and delay as equated to existing methods with 23.95% and 20%, respectively.

Table 5. Comparison analysis of proposed with existing methods for PDR.

Node	Proposed	SRN-LEACH [24]	EE-LEACH [23]	DEE [22]
100	0.985	0.979	0.96	0.95
200	0.978	0.970	0.96	0.94
300	0.99	0.985	0.95	0.94
400	0.995	0.988	0.97	0.95
500	0.995	0.986	0.96	0.94

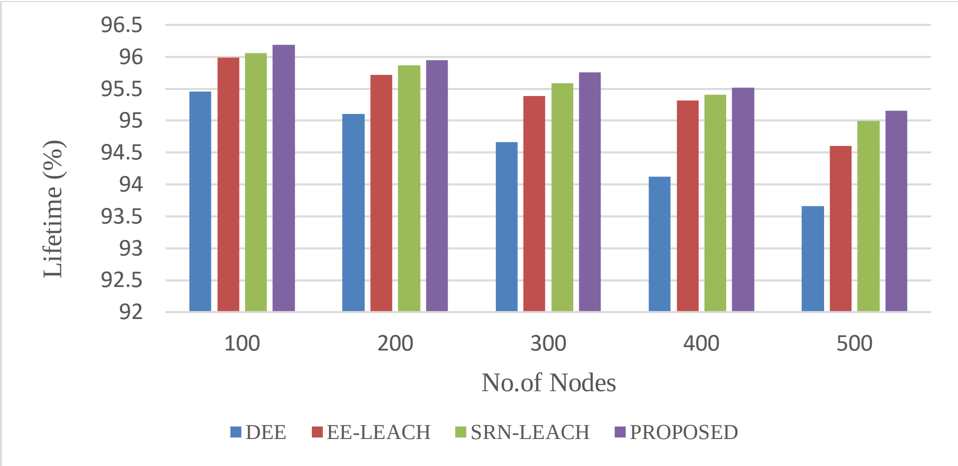

Fig.5. Performance comparison graph of network lifetime.

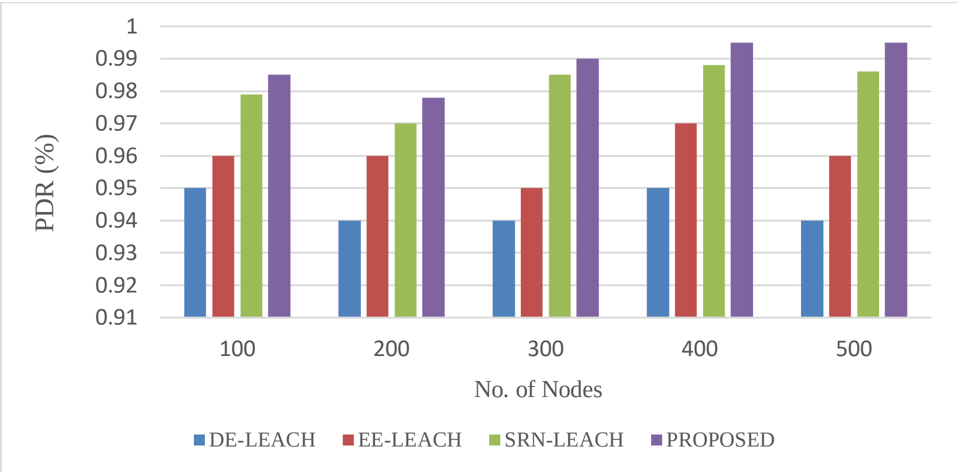

Fig.6. Graphical representation of PDR.

Table 6. Comparison analysis of proposed with existing methods for throughput.

Node	Proposed	SRN-LEACH [24]	EE-LEACH [23]	DEE [22]
100	387	358	340	309
200	388	362	341	308
300	390	358	339	308
400	389	371	342	309
500	389	377	344	311

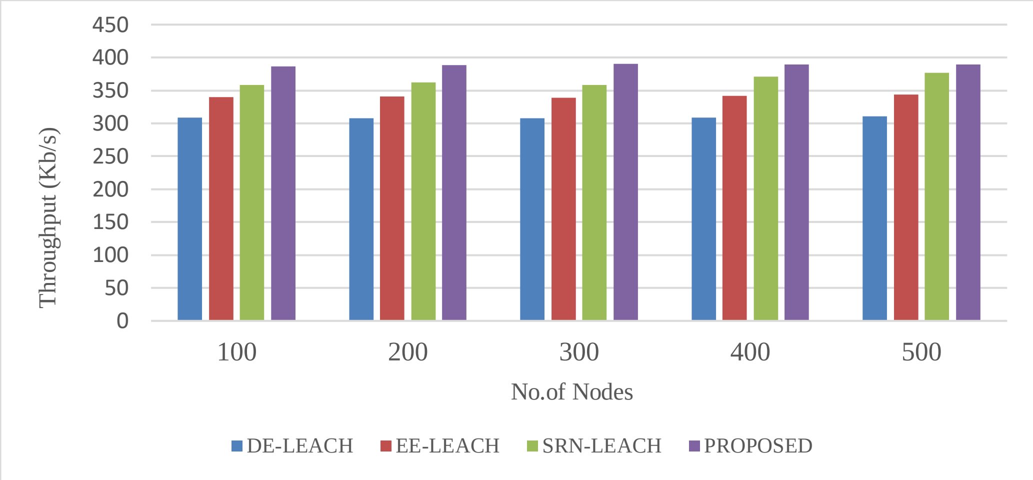

Fig.7. Throughput comparison obtained using existing and proposed methods.

5. Conclusions

This article proposed a new and improved LEACH-based clustering algorithm called CER-LEACH, for enhancing the overall system performance in terms of network lifetime, energy efficiency, and reliability. In addition, the energy efficiency, CH stability and secure data transmission is improved by proposing SS-LEACH approach. Further, this method also introduced a HRDT scheme for secure data transmission, where this reputation rate determines the reliability and trustworthiness of the sensor nodes. Finally, the simulation results and analysis show that proposed CER-LEACH achieved much better performance of WSN in terms of energy dissipation, network lifetime, and secure communication as compared to state-of-art approaches. The obtained results shown significant enhancement in all quality metrics such as 3.4%, 0.7%, and 0.13% increment in throughput, PDR, and lifetime, respectively. In addition, the proposed method mitigated the 23.95% of energy, and 20% of delay as equated to existing methods.

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Authors' Profiles

S. Ravi Kumar, pursuing PhD in JNTUH under the guidance of Dr. D. Sreenivasa Rao, Professor, ECE Department, JNTUH. He has completed Post Graduated in Electronics and Communication Engineering M. Tech from Andhra University, Visakhapatnam in 2005 and Graduated in Electronics and Communication Engineering (B. Tech) from JNTU, in 2002. He is working as Associate Professor in Department of Electronics and Communication Engineering in St. Martin's Engineering College, R.R. Dist., TS, India. He has 16 years of Teaching Experience. His Research area in PhD is Energy Efficient Routing for Wireless Sensor Networks.

Dr. D. Sreenivasa Rao completed PhD from University of Hyderabad with Computer Networks Specialization in the year 2004. He has completed ME from Osmania University, Hyderabad with Digital Systems Specialization in the year 1994. He has completed B. Tech from Nagarjuna University, Vijayawada in the year 1986 with Electronics and Communications engineering Specialization. Currently, he is working as Professor in ECE department at College of Engineering, JNTUH, Hyderabad, Telangana. He has guided 13 Ph.D. scholars till date and guiding many more. He had more than 150 national, and international publications in various journals and conferences. His research interested areas are computer network security, energy efficiency, and routing protocols.

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