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IoT aware Energy Indexed Theil-Sen Linear Regressive Timeinstantaneous Data Transmission in WSN

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Abstract
Wireless Sensor Network is self-organizing multi-hop sensor nodes that communicate with each other through wireless communication. The sensor node monitors the environmental conditions and collects the data transmitting and receiving the data from/to several nodes. During the data transmission, energy is the most important parameter to enhance the overall network lifespan. In general, the sensor nodes have low energy but big data transmission causes a major problem in WSN.

A novel machine learning technique called IoT aware Energy Indexed Theil-Sen Linear Regressive Time Instantaneous Data transmission (IoT-ETLR) is introduced to improve the network lifetime in WSN. Theil-Sen Linear Regression Analysis is carried out in IoT-ETLR to analyze the residual energy of the sensor nodes based on Camargo's index. Theil-Sen regression analysis is a machine learning method used for estimating the relationship between one or more variables. The regression analysis is linear regression that identifies the higher energy-efficient sensor nodes. After that, the route path discovery between the source and sink node via neighboring higher energy sensor nodes is based on the Time difference of the arrival method. Finally, the route path gets constructed and data transmission is carried out in efficient manner. Experimental evaluation is carried out on factors such as energy consumption, packet delivery ratio, packet loss rate, end to end delay with respect to the different number of sensor nodes and data packets. The observed results indicate that our proposed IoT-ETLR technique provides a better results in energy-aware data transmission with a higher delivery ratio and lesser delay than the state-of-the-art works.

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1. INTRODUCTION

A WSN comprises spatially scattered sensor nodes meant to monitor and collect the variety of physical and environmental conditions with the help of the Internet of Things (IoT). The different types of sensor nodes are generally energy disposed of in nature which directs to the formulation of novel techniques to limit any redundant energy dissipation. The source nodes in the wireless network consume a lot of energy in communicating data. A comparative study of different routing techniques has been developed to enhance network lifetime. Energy Soaring-based Routing Algorithm (ESRA) was designed in [1] for IoT Applications to monitor the environment and enhance the network lifetime as well as minimize the delay. However, higher data delivery was not achieved between the source and sink node. A Q-learning-based data aggregation-aware energy-efficient routing (Q-DAEER) technique was designed in [2] to find the best path for enhancing the lifetime and minimizing energy consumption of the network. However, the designed Q-DAEER technique failed to consider the delay-aware routing.

Power-Efficient Gathering in Sensor Information Systems (PEGASIS) was introduced in [3] to transmit packets for energy-balanced WSNs. But the performance analysis of packet delivery and loss rate was not carried out. Region-Based Mobile (RBM) Routing Protocol was designed in [4] for Wireless Sensor Networks. The region-based routing consumes more time for effectively transmitting the data packets. An Original Queen Honey Bee Migration (QHBM) technique was introduced in [5] for solving efficient mobile routing. However, higher data delivery was not achieved. An energy-efficient deep belief network (DBN) based routing method was introduced in [6] to achieve improved data transmission via the selected path. The selection of the shortest path was not performed for efficient data transmission to enhance network lifetime and energy efficiency.

An Improved Stable Election Protocol (I-SEP) was introduced in [7] for IoT-based Environmental Monitoring. However, the algorithm was not applied for a mobile network where sensor nodes progress from one point to another with a stable speed. An efficient data transmission model was introduced in [8] for next-hop node selection for data transmission throughout the network. But it failed to maximize the data routing balance among the IoT nodes. A neighbor discovery algorithm with k-hop clustering schemes was developed in [9] with the aim of focusing on IoT-aware data communications. However, the designed schemes failed to analyze the complexity of algorithms. An energy-aware routing protocol based on an optimization algorithm was introduced in [10]. However, the performance analysis packet delivery ratio was not focused.

Contribution of work

A novel IoT-ETLR technique is introduced for solving the existing issues with the following major contributions.

- To improve energy-efficient data transmission, a novel technique called the IoT-ETLR technique is developed based on three processes namely energy-efficient node selecting, route path discovery, and route maintenance.
- Theil-Sen Linear Regression is applied in IoT-ETLR to analyze the residual energy of the sensor nodes based on Camargo's index. Based on the similarity index value, the higher energy and lesser energy nodes are identified. Then the route paths are constructed with higher energy nodes using the Time difference of the arrival method for improving the data delivery and extending the network lifetime.
- To minimize packet loss and delay, route maintenance is performed in IoT-ETLR. If any link failure occurred in the route path, the node finds the alternative route with the help of routing table information.
- Finally, the simulation was conducted to compare the performance of the proposed IoT-ETLR with respect to existing methods based on different metrics.

Organization of Paper

The rest of the paper is arranged into five different sections as follows: Here, section 2 reviews the literature. Section 3 describes the proposed IoT-ETLR technique in detail. In Section 4, simulations settings are presented. In Section 5, the performance of proposed and existing methods is compared with different performance metrics. Finally, Section 5 concludes the paper.

2. RELATED WORKS

Three different algorithms were developed in [11] to improve the performance of a sensor network using nature-inspired computational methods. However, it failed to minimize the time complexities of optimizing the solution. A dynamic multi-hop energy-efficient routing protocol (DMEERP) was designed in [12] for WSN. However, it failed to balance the energy of data transmission. A Dynamic Routing Algorithm Based On Energy-Efficient Relay Selection (DRAWERS) was introduced in [13]. However, the complexity of DRA-EERS was increased while increasing the network size. An Energy-Efficient Cooperative Routing method was designed in [14] for Heterogeneous WSN. However, the performance analysis of delivery and loss rate was not focused.

Distance Aware Residual Energy- Efficient Stable Election Protocol (DARE-SEP) was designed in [15] to provide an optimal transmission from sensor nodes to the other node. But it failed to maximize the network lifetime and protect the total energy of the network. A composite fuzzy solution for energy-efficient routing was designed in [16] for WSN. But it failed to improve the data transmission for better energy consumption. An energy-efficient routing using the hybrid optimization algorithm was designed in [17] for selecting optimal hops to improve the routing process. But the performance of data transmission was not efficient to enhance the data delivery.

Learning Automata-based Routing method was developed in [18] for WSN to achieve energy efficiency and better data delivery. However, the designed method failed to consider the node mobility and energy harvesting nodes. Distributed energy-efficient clustering protocol was introduced in [19] for cooperative routing transmission. But it failed to include the machine learning techniques into the heterogeneous for improving the routing performance. Extended Power-Efficient Gathering in Sensor Information Systems (E-PEGASIS) protocol was developed in [20] for improving the data transmission. However, the delay of data transmission was not minimized.

3. PROPOSAL METHODOLOGY

In recent years, huge attention and dramatic development have been exposed for the Internet of Things (IoT) based constrained Wireless sensor network (WSN) to attain efficient resource utilization and better data transmission. IoT requires a better communication network for data transmission between heterogeneous devices and an optimally organized energy-efficient WSN. An IoT node is a small device and the delivered power is generally provided by batteries. Therefore, energy is a major constraint in the designing process of a WSN. In this paper, a novel technique called IoT-ETLR is introduced to attain a better network lifetime by performing the energy-efficient routing in WSN.

SYSTEM MODEL

The system model of the proposed IoT-ETLR architecture is discussed in this subsection. In WSN, the number of IoT aware sensor nodes $S_i \in SN_1, SN_2, N_3 \dots SN_n$ are randomly positioned in a squared grid structure '$m * m$' regarding certain transmission range 'T_R' to collect the environmental conditions from the environment. The collected data is transferred into the sink node in terms of data packets '$Dp_j = Dp_1, Dp_2, \dots, Dp_m$ with the help of energy-efficient intermediate neighboring nodes ' $In_1, In_2, \dots, In_n$ to expand the network lifetime.

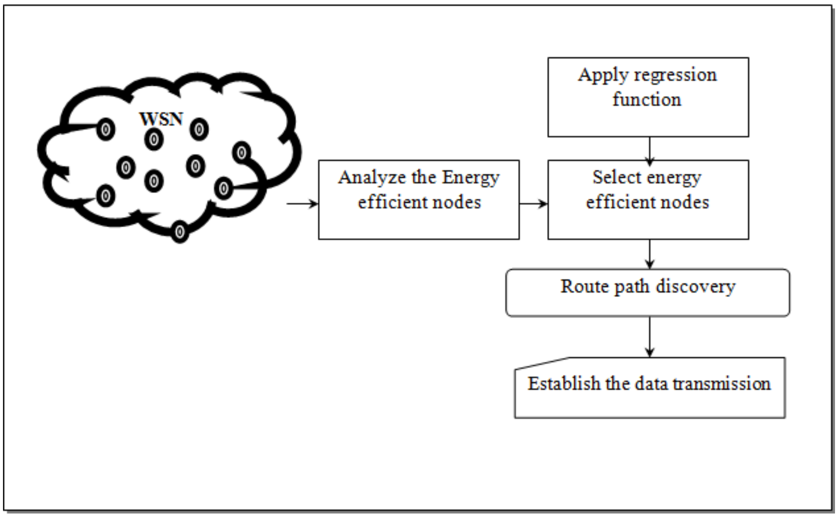

Figure 1 Architecture of the Proposed IoT-ETLR Technique

Fig.1. shows the architecture diagram of the proposed IoT-ETLR technique used for improving the data transmission with minimum delay and better network lifetime. The IoT aware WSN comprises sensor nodes $S_i \in SN_1, SN_2, SN_3 \dots SN_n$ for data transmission from source to sink node. The proposed IoT-ETLR technique consists of three different processes such as energy-efficient node selection, route discovery, and route maintenance. First, the Theil-Sen linear regression is applied for finding the energy-efficient sensor nodes. Second route path discovery is performed between sources to sink node based on time of flight method. Finally, the data transmission is performed along the route path.

CAMARGO'S INDEXIVE THEIL-SEN LINEAR REGRESSION

The first process of the proposed IoT-ETLR technique is to find the energy-efficient sensor nodes among the numerous sensor nodes. Energy efficiency is the most essential parameter in the design process of any routing technique in WSN. Therefore, energy-efficient nodes are identified through the Theil-Sen linear regression. Regression analysis is a set of statistical processes for measuring the relationships between the dependent variable (i.e. Sensor nodes) and one or more independent variables (i.e. energy). The most common form of regression analysis is most closely finding the energy-efficient nodes according to a specific mathematical criterion. Theil-Sen linear regression uses Camargo's index for finding the energy-efficient nodes.

Initially, all the sensor nodes have similar energy levels. The energy of the sensor node is formulated as given below,

$$\varphi(S_i) = pr * ti \quad (1)$$

Where, '$\varphi(S_i)$' designates the energy level of the sensor nodes, 'pr' indicates a power measured in terms of watts, and ti denotes a time measured in seconds (Sec). The energy of each sensor node is measured in joule (J). The original energy level of the node gets minimized during the sensing and monitoring the environmental conditions in WSN. The residual energy level of sensor nodes are estimated as given below,

$$\varphi_{(R)}(S_i) = T_{\varphi_E} - C_{\varphi_E} \quad (2)$$

From (2), '$\varphi_{(R)}$' represents the residual energy of the node, T_{φ_E} indicates total energy (i.e. initial energy) of the sensor nodes, C_{φ_E} denotes the consumed energy of the sensor nodes. The residual energy of the sensor nodes is given to the Theil-Sen linear regression

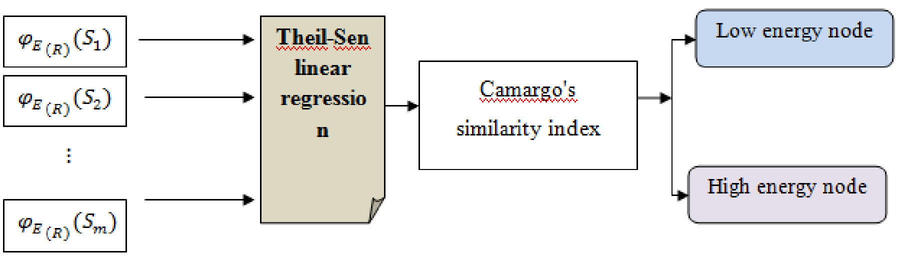

Figure 2 Camargo's indexive Theil-Sen linear regression

Fig.2. illustrates Camargo's indexive Theil-Sen linear regression that classifies the sensor nodes into high or low energy sensor nodes. First, the residual energy of the sensor nodes is given to the regression function. Then Camargo's similarity index is applied to measure the residual energy of node and median (i.e. threshold value) as given below,

$$CI = 1 - \left(\frac{\varphi_{(R)}(S_n) - M(\varphi_{E(R)})}{n}\right) \quad (3)$$

Where, CI denotes a Camargo's similarity index, $\varphi_{(R)}(S_n)$ denotes residual energy of the sensor node, $M\ (\varphi_{E(R)})$ denotes a median (i.e.) threshold, 'n' denotes the number of sensor nodes. The Camargo's similarity index provides a value between 0 and 1.

$$CI = \begin{cases} 0.5 > CI, & Higher\ energy\ nodes \\ 0.5 < CI, & Lesser\ energy\ nodes \end{cases} \quad (4)$$

From (4), the higher energy nodes are identified when the CI index is greater than the 0.5. Otherwise, the nodes are identified as lesser energy nodes. In this way, all the higher energy sensor nodes are identified for efficient data delivery from source to sink node.

TIME DIFFERENCE OF ARRIVALMETHOD BASED ROUTE PATHDISCOVERY

The second process of the proposed IoT-ETLR technique is to find the Route path between source and sink node through the higher energy sensor nodes. In the route discovery phase, a source node in the WSN tries to discover a path to a specific destination i.e. sink node. The discovered path is used by the source node as the pathway for all communication until the discovered path becomes invalid. Therefore, the proposed IoT-ETLR technique uses the Time difference of the arrival method to find the neighboring sensor nodes through the Route request and reply message distribution.

By applying a Time difference of arrival method, the source node sends the Route request message to all the sensor nodes.

$$SO \overset{Rrq}{\rightarrow\rightarrow} \sum_{i=1}^{n} S_i \qquad (5)$$

From (5), SO denotes a source node, S_i indicates other sensor nodes, rq denotes a route request. After receiving the request, the sensor node sends a route reply message to the source node.

$$\sum_{i=1}^{n} S_i \overset{Rrp}{\rightarrow\rightarrow} SO \qquad (6)$$

From (6), SO denotes a source node, S_i indicates other sensor nodes, rp denotes a route request. Based on the arrival time of the reply message, the neighboring sensor nodes are identified as follows,

$$TD = {}_{ARrp} - T_{SRrq} \qquad (7)$$

Where TD indicates a Time difference, T_{ARrp} denotes a time of arrival time of the reply message, T_{SRrq} denotes a time of request sending. The Time difference of the arrival method is defined as the difference between the reply arrival time and request sending time at the source node. The node which has a minimum time difference is selected as a neighboring node. In this way, the route path from source to sink node is established via neighboring sensor nodes.

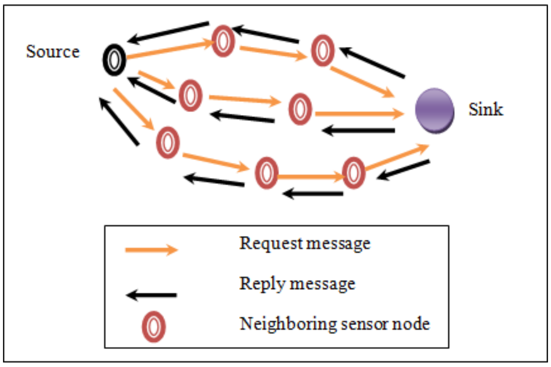

Figure 3 Route Path Discovery

Fig.3. illustrates the route path discovery between sources and sink nodes to perform data packet transmission.

DATA PACKET TRANSMISSION

Finally, the proposed IoT-ETLR technique performs the data packet transmission from source to sink node. During the transmission of data, there is a possibility of route failure. In this case, route maintenance is performed between the nodes. In this proposed technique, each source and other nodes have a routing table that establishes various paths in the route discovery phase and they are stored in their route collections. Table 1 Routing Table

Source ID	Destination ID	Paths stored in the route	Number of hop counts	Next hop

Table 2 shows the routing table of sensor nodes. The sensor nodes store all paths in the routing table. In case of route failure in the main route, a node selects the alternative route for efficient data transmission and minimizes the delay. In this way, efficient data packets transmission is performed from source to destination. The algorithm of IoT-ETLR is described as given below.

Algorithm 1: IoT aware Energy Indexed Theil-Sen Linear Regressive Time Instantaneous Data transmission
Input: Sensor nodes $SN_1, SN_2, SN_3 \dots SN_n$ data packets $Dp_j = Dp_1, Dp_2, \dots, Dp_m$ **Output**: Increase data delivery and minimize delay
Step 1: **for each** sensor node S_i **Step 2:** **Calculate residual energy** '$\boldsymbol{\varphi_{E_{(R)}}(S_i)}$' **Step 3:** Apply Theil-Sen linear regression to measure the similarity **Step 4**: $\boldsymbol{if}$ $(CI > 0.5)$ **then** **Step 5**: Sensor nodes are identified as high energy **Step 6:** **else** **Step 7:** Sensor nodes are identified as low energy **Step 8:** **end** $\boldsymbol{if}$ **Step 9:** $\boldsymbol{SO}$ sends the **route** request $SO \xrightarrow{Rrq} \sum_{i=1}^{n} S_i$ **Step 10**: Neighboring node sends reply $\sum_{i=1}^{n} S_i \xrightarrow{Rrp} SO$ **Step 11**: **Measure** Time difference 'TD' **Step 12**: Create route paths **Step 13**: Deliver the data packets to the sink node along the route path **Step 14:** **If** any route failure

Step 15: Select an alternative route
Step 16: End if
Step 17: Obtain efficient data delivery
End

Algorithm 1 given above describes the step-by-step process of energy-efficient data transmission using IoT-ETLR in WSN. First, the high-energy efficient nodes are identified using Theil-Sen linear regression for measuring Camargo's similarity index. After that, the Time difference of the arrival method is applied to find the multiple route paths between the sensor nodes based on route request and route reply. The route path discovery between the source and sink node via neighboring higher energy sensor nodes is established based on theTime difference of the arrival method. Finally, the route path gets constructed and data transmission is carried out in an efficient manner. In case of any route failure, the route maintenances are carried out to minimize the delay of data transmission.

4. SIMULATION SETTINGS

In this section, simulations of the proposed IoT-ETLR technique and existing methods namely ESRA[1], Q-DAEER [2] are implemented using the NS2.34 network simulator. In order to conduct the simulation, 500 sensor nodes are distributed in a squared area $(1100\ m * 1100\ m)$ in WSN. A Random Waypoint model is used as a mobility model. The sensor nodes are distributed in the network with a speed of 0 to 20m/sec. The total simulation time is set as 300 sec. The Dynamic Source Routing (DSR) protocol is used for energy efficient data transmission in WSN. The parameters used for the simulation are listed in Table 2.

Table 2 Simulation Parameters Settings

Simulation parameters	Values
Network Simulator	NS2.34
Simulation area	1100 m * 1100 m
Number of sensor nodes	50,100,150,200,250,300,350,400,450,500
Number of data packets	100,200,300,400,500,600,700,800,900,1000
Mobility model	Random Waypoint model
Nodes speed	0 - 20 m/s
Simulation time	300sec
Routing Protocol	DSR
Number of runs	10

5. PERFORMANCE ANALYSIS

Simulation analysis of IoT-ETLR technique and existing methods ESRA[1], Q-DAEER [2] are discussed with different performance metrics such as energy consumption, packet delivery ratio, packet loss rate, and end to end delay.

Energy consumption: It is calculated as the amount of energy consumed by the sensor nodes to transfer the data packets from the source to the sink node. The overall energy consumption of the sensor node is formulated as given below,

$$CS_E = \sum_{i=1}^{n} S_i * CS_E\,(SSn) \quad (8)$$

From (8), CS_E symbolizes the energy consumption, 'S_i' indicates the number of sensor nodes, $S_E\ (SSn)$ denotes energy consumption of single sensor nodes. The overall energy consumption is measured in terms of joule (J).

Table 3 Energy Consumption Versus Sensor Nodes

Sensor nodes (Numbers)	Energy consumption (J)		
	IoT-ETLR	**ESRA**	**Q-DAEER**
50	21	25	27
100	23	26	28.5
150	26.25	28.5	33
200	30	33	36
250	33.75	35.25	37.5
300	36.6	39	42
350	40.25	42	44.45
400	44.8	48.4	50.4
450	47.25	50.85	52.2
500	51.5	54	57

Table 2 reports the performance evaluation results of energy consumption based on the number of sensor nodes. For simulation purposes, a number of sensor nodes are taken from 50 to 500. The performance of energy consumption is measured using three methods IoT-ETLR technique and existing methods ESRA[1], Q-DAEER [2]. The reported results illustrate that the IoT-ETLR provides better performance in terms of achieving lesser energy consumption than the conventional routing techniques. Let us consider the 50 sensor nodes to calculate the energy consumption. By applying the IoT-ETLR technique, the energy consumption of data transmission is observed by $21J$ and the energy consumption of data transmission using [1] [2] are $25J$ and $27J$. Likewise, various results are observed for each method. Then the observed results of the IoT-ETLR technique are compared to the results of existing [1] [2]. After that, the average is taken for all the comparison results. Finally, the average result indicates that the overall energy consumption of the IoT-ETLR technique is reduced by 8% when compared to [1] and 14% when compared to [2].

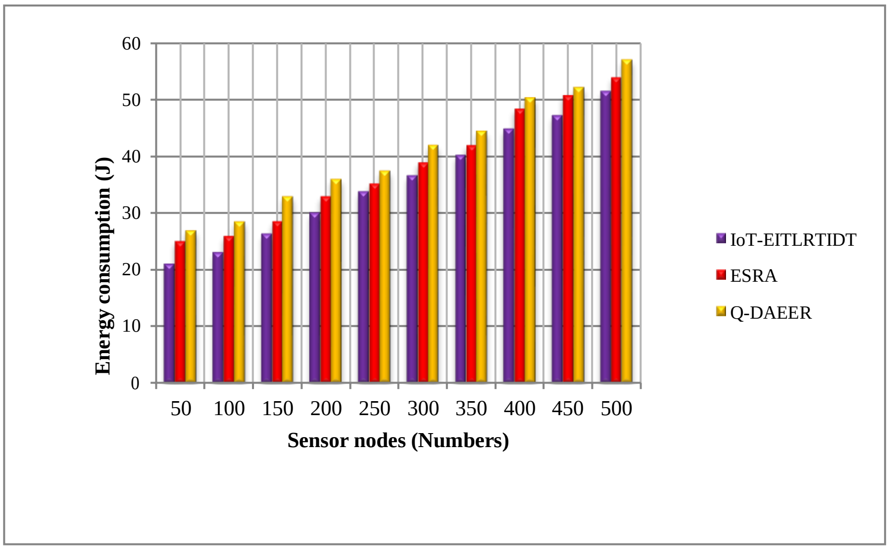

Figure 4 Graphical Analysis of Energy Consumption

Figure 4 demonstrate the performance analysis of energy consumption versus a number of sensor nodes. As shown in the graph, the number of sensor nodes is taken in the horizontal axis and the performance of energy consumption is observed in the vertical direction. Therefore, the energy consumption of the different methods is denoted by the three different colors such as violet, red, and orange respectively. As revealed in the above figure 4, the energy consumption of the proposed IoT-ETLR technique is considerably increased when compared to other methods. This is due to the application of Theil-Sen Linear Regression to analyze the residual energy of the sensor nodes based on Camargo's similarity index. The higher energy nodes are selected for data transmission hence it improves the network lifetime.

Packet delivery ratio: It is formulated as the ratio of the number of data packets that are successfully delivered at the sink node to the total number of data packets sent. The formula for calculating the packet delivery ratio is given below,

$$DpD = \left(\frac{DpSD}{nDp}\right) * 100 \quad (9)$$

Where, DpD signifies a packet delivery ratio, $DpSD$ indicates the number of packets successfully delivered, nDp represents the number of data packets. The packet delivery ratio is measured in percentage (%).

Table 4 Packet Delivery Ratio Versus Number of Data Packets

Number of data packets	Packet delivery ratio (%)		
	IoT-ETLR	ESRA	Q-DAEER
100	91	89	87
200	90	88	85.5
300	91.66	89.33	85
400	91	87	84
500	90.2	86.6	84.2
600	92.5	87.5	85.83
700	91.71	88.85	86.42
800	91.5	88.75	85.62
900	91.22	87.77	84.44
1000	90.5	87.5	83.5

Performance analysis of packet delivery ratio versus the number of data packets is reported in table 4 and figure 5. The above results indicate that the performance of the IoT-ETLR technique is comparatively higher than the conventional methods. Let us consider the 100 data packets and the number of data packets successfully delivered to the sink node is 91 data packets. Therefore, the percentage of packet delivery ratio is 91%. By applying the existing methods ESRA[1], Q-DAEER [2], the 89 and 87 data packets are successfully delivered at the sink node, and observed delivery ratios are 77% and 87%. Likewise, nine remaining results are observed for all three methods. Totally, ten results are obtained and compared. The comparison results designate that the overall packet delivery ratio of the proposed IoT-ETLR technique is considerably improved by 4% and 9% when compared to [1] [2] respectively.

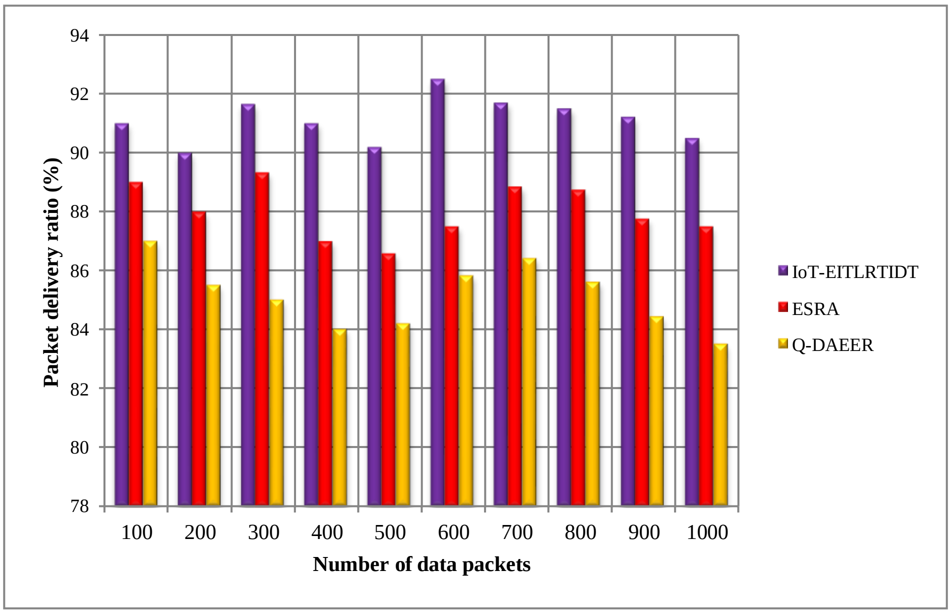

Figure 5 Graphical Analysis of Packet Delivery Ratio

This improvement of the proposed IoT-ETLR technique is to apply the Time difference of the arrival method. The multiple route paths are established between the source and sink node by distributing the route request and reply messages. Based on the message distribution, the time difference between the request sending and reply arrival is measured to identify the neighboring node and construct the route path. This process helps to successfully deliver the data packets to the sink node.

Packet loss rate: It is measured as the ratio of the number of data packets lost to the total number of data packets sent from the source node. Therefore, the overall loss rate during the data transmission is measured as follows,

$$DpL \ = (\frac{DpL}{nDp}) * 100 \quad (10)$$

Where DpL represents the data packet loss rate, DpL indicates number of data packets lost, nDp represents the number of packets sent. The packet loss rate is measured in percentage (%).

Table 5 Packet Loss Rate Versus Number of Data Packets

Number of data packets	Packet loss rate (%)		
	IoT-ETLR	ESRA	Q-DAEER
100	9	11	13
200	10	12	14.5
300	8.33	10.66	15
400	9	13	16
500	9.8	13.4	15.8
600	7.5	12.5	14.16
700	8.28	11.14	13.57
800	8.5	11.25	14.37
900	8.77	12.22	15.55
1000	9.5	12.5	16.5

Table 5 and Figure 6 given above illustrate the performance analysis of packet loss rate for varying numbers of a number of data packets collected from 100 to 1000. The observed results show that the loss rate during the data packet transmission is minimized using the proposed IoT-ETLR technique when compared to the existing routing methods. This is proved through numerical analysis. Let us consider the 100 data packets being sent from the source node. The loss rate using the IoT-ETLR technique is found to be 9% whereas the loss rates of exiting methods ESRA[1], Q-DAEER [2] are 11% and 13% respectively. From the analysis, the observed ten results of the IoT-ETLR technique are compared to existing methods. The overall comparison results indicate that the packet loss rate is comparatively minimized by 26% and 40% using IoT-ETLR when compared to existing methods. The node which has higher energy and the minimum distance is selected for efficient data delivery resulting in minimizes the packet loss.

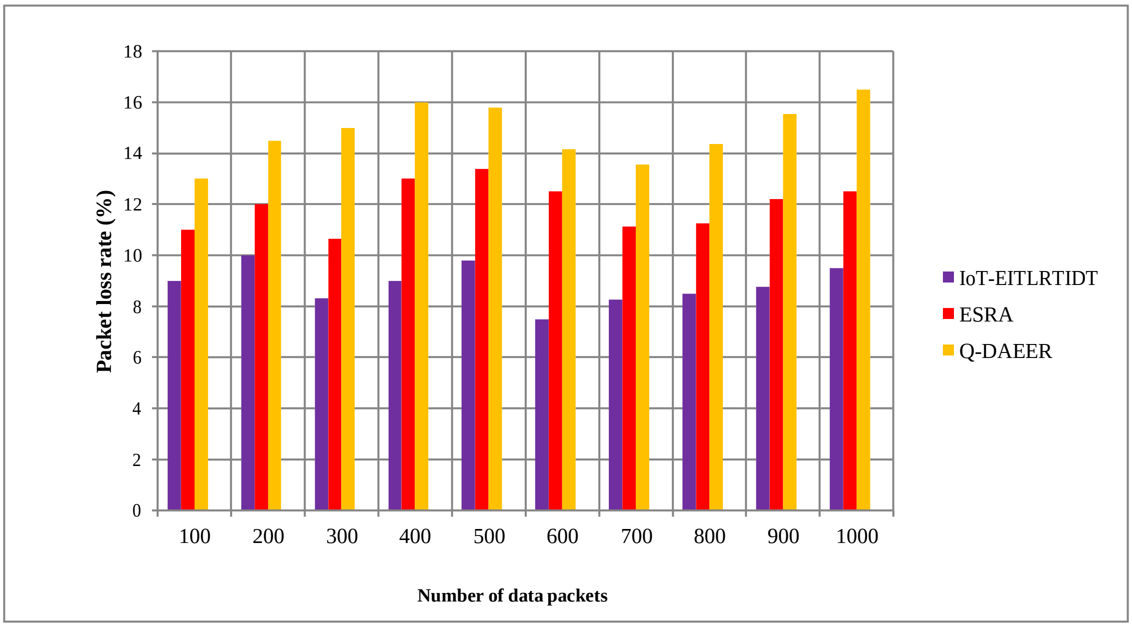

Figure 6 Graphical analysis of Packet loss rate

End-to-end delay: It is measured as the difference between the actual arrival time of the data packets at the sink node and the expected arrival time. It is formulated as given below,

$$DEL = [T_A] - [T_{EX}] \quad (11)$$

Where DEL' indicates an end to end delay, T_{AC} indicates an actual arrival time T_{EX} designates an expected arrival time. The delay is measured in terms of milliseconds (ms).

Table 6 End to End Delay Versus Number of Data Packets

Sensor nodes (Numbers)	end to end delay (ms)		
	IoT-ETLR	ESRA	Q-DAEER
50	14.3	15.8	18.2
100	15.4	17.3	20.1
150	16.7	18.3	21.2
200	18.3	20.1	23.4
250	21.5	23	25.3
300	24	26.2	28
350	27.3	30.1	32.5
400	29.1	32.5	35.3
450	31.1	34.6	37.2
500	33.4	36	38.6

Table 6 given above illustrates the performance results of end-to-end delay of data packet transmission versus a number of sensor nodes. The observed simulation results indicate that the proposed IoT-ETLR technique provides better performance in terms of minimizing the delay than the conventional routing methods. For example, the number of nodes considered is 50 in the first iteration. The end-to-end delay of the IoT-ETLR technique is $14.3ms$ whereas the performance of delays using conventional methods ESRA[1], Q-DAEER [2] are $15.8ms,$ and $18.2ms$ respectively. The overall observed statistical analysis demonstrates that the proposed IoT-ETLR technique provides better routing performance by minimizing the delay than the conventional methods. The average of ten comparison results designates that the overall end-to-end delay of the IoT-ETLR technique is considerably minimized by 9% when compared to [1] and 18% when compared to [2] respectively.

Figure 7 presents the graphical results of an end-to-end delay along with a number of sensor nodes. The end-to-end delay of all the methods gets increased while increasing the number of sensor nodes. But comparatively, the proposed IoT-ETLR technique provides a lesser delay in order to accurately perform the data transmission. The IoT-ETLR technique is to perform route maintenance. During the data transmission, any link between the nodes is broken, another alternative link path is efficiently chosen and improves the data delivery between the nodes resulting it minimizing the end-to-end delay.

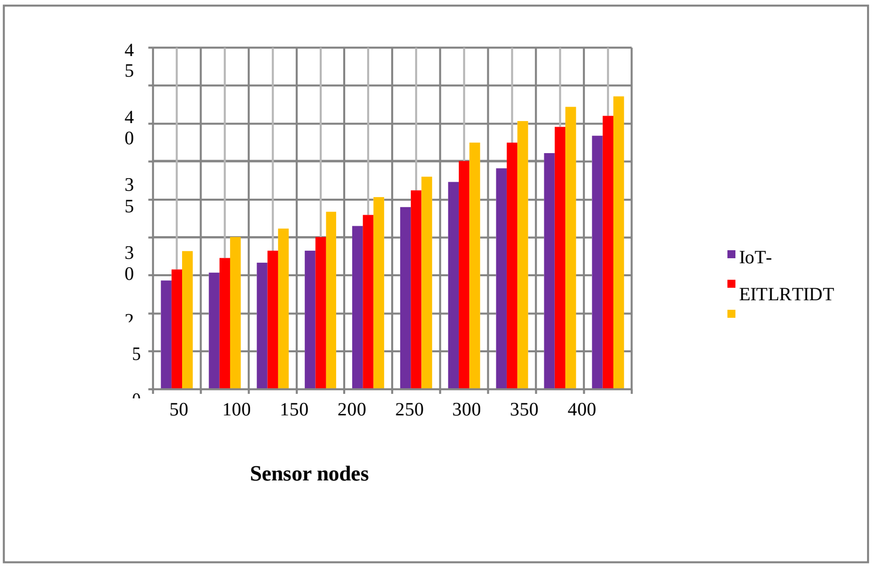

Figure 7 Graphical Analysis of End to End Delay

6. CONCLUSION

In this paper, a novel energy-efficient technique called the IoT-ETLR technique is introduced to enhance the network lifetime. The proposed IoT-ETLR technique performs three major processes. First, the Theil-Sen Linear Regression is applied to analyze the residual energy of the sensor nodes and find the higher energy nodes based on Camargo's similarity index. After that, the multiple route paths between the source and sink nodes are established by applying a Time difference of arrival method. Finally, the route maintenances are carried out to improve data transmission and minimize the delay. The simulation analysis is carried out on certain performance factors such as energy consumption, packet delivery ratio, packet loss rate, and end-to-end delay. The observed result shows that the proposed IoT-ETLR technique provides better results has a higher delivery ratio and minimizes packet loss, delay, as well as energy consumption than the conventional methods.

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