Mechanism To Improve Packet Delivery Ratio In RPL Networks (EDPS)

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Abstract-- The Internet of Things (IoT) is an innovative technology that helps in performing tasks from anywhere and anytime. The best example of the immense use of IoT is during the present pandemic period when much of the work is performed by using the IoT sensor over the Internet. The IoT sensors collect the data from the environment and the data are transferred to the owner through the network. The network may be wired or wireless. Although the use of Internet of Things (IoT) has become very popular in many day-to-day applications, a lack of Quality of Service (QoS) due to routing issues has diminished its wide adaptability. Quality of Service is determined based on the service experienced by the user. QoS plays a major role in routing and is considered an important factor for better performances. Hence, it is necessary to consider the QoS metrics such as Packet delivery ratio, packet loss, throughput and delay for efficient routing of data from the sensor to the storage. The objective of this work is to propose a mechanism to enhance the parent-selection technique to avoid node failure by considering residual energy, which reduces packet loss and increases throughput in RPL (Routing Protocol for Low power and Lossy network).

Keywords— Internet of Things (IoT), RPL (Routing Protocol for Low power and Lossy network), Delay, Packet delivery ratio and throughput

I. INTRODUCTION

In the Internet of Things, various protocols are used for routing. Each layer of IoT employs different protocols, such as a separate protocol for the application layer and a separate protocol for the network layer. This research work focuses on the routing protocol namely RPL (Routing Protocol for Low power and Lossy network) used in the network layer. The developed protocol is Ipv6 based and is specifically designed for the IoT by the Internet Engineering Task Force (IETF).

The main aim of the objective functions is to construct a stable path to transfer the packet by finding the nearest node with minimal packet loss and with a high packet delivery ratio. To find the nearest node, the rank of every neighbour node is calculated. Each objective function uses a different approach to calculate the rank value to construct the path.

It is observed that some issues such as node failure, energy and congestion in the existing rank calculation methods tend to pull down the performance of RPL. To overcome node failure and to reduce energy consumption while routing, a new mechanism is introduced in RPL. This work elaborates on the existing rank calculation method in RPL, issues that have to be tackled, proposed mechanism, results and discussion.

RPL

In the RPL protocol, the Rank value is calculated based on the Objective Function (OF). The objective function is used to construct the path to transfer the packet from source to destination. There are three types of objective functions. The existing objective functions used to calculate the rank are OF0 (ETX) Excepted Transmission Count and OF1 (HOP). Each objective function uses a different formula to calculate the rank value to construct the path protocol.

RPL is a protocol, which is designed for the IoT. Routing of the packet will begin after the construction of the DODAG. The objective function used to construct DODAG will support the static nodes. In a network, the node with minimum lifetime is identified while the error occurs, and an alternative path selection method is introduced to reconstruct the path.

Quality of Service (QoS)

Quality of Service (QoS) plays a vital role in routing. QoS is determined based on the performance of the metrics. QoS metrics are classified into two categories such as Node metrics and Link metrics. The following figure 1 illustrates the basic classification of QoS routing metrics.

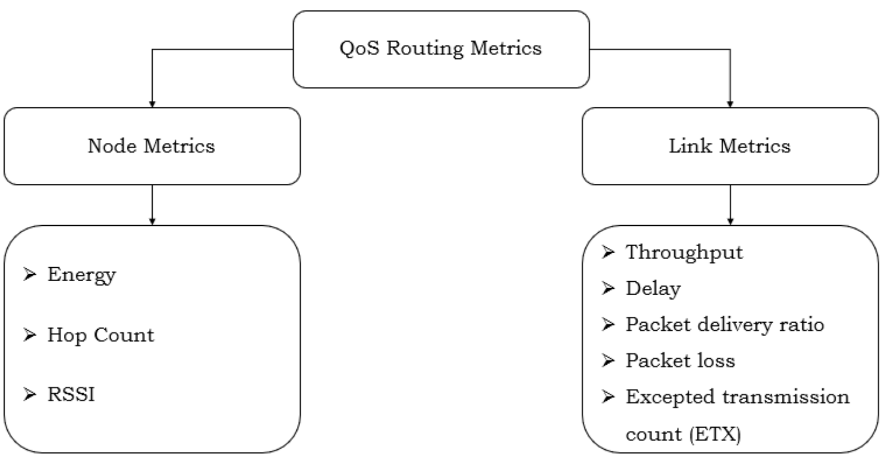

Figure 1: Classification of QoS Routing Metrics

Received Signal Strength Indicator (RSSI)

RSSI Stands for Received Signal Strength Indicator. RSSI concept is used to calculate the rank value of the Neighbour node. Based on the signal received by the node, the RSSI value is calculated. In general, RSSI, the signal value from 0 to -30 dBm is referred to as a good signal, -31 to -60 dBms indicates a medium signal, and -61 to -90 dBm is a weak signal. When the signal value goes above -90 dBm, then it is considered to be a bad signal. Depending on the above values of the RSSI the node's position is identified. The maximum communication range of Bluetooth dongle is 100cm., the minimum RSSI value is 0dBm and the maximum RSSI value is 30.5. Since a homogenous network is considered in this work, the maximum range of communication is 700cm.

After getting the RSSI value, the distance value is calculated. Based on the distance, the rank value is calculated. These values help the root node to construct the path to transfer the packet without any packet loss or packet mishap or replacement of packet. This objective function helps the RPL to improve the performance of the Path construction.

This rank calculation method helps the RPL to improve the performance of the RPL. Problems like parent selection, congestion, delay, energy consumption and so on are the issues that affect the performance of the RPL protocol.

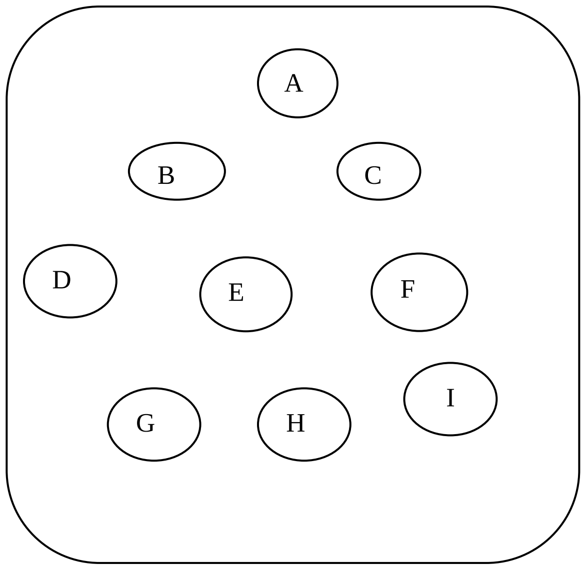

Figure 2: RPL Scenario-1

Figure 2 shows an RPL DODAG construction scenario. The full form of DODAG is Destination-Oriented Directed Acyclic Graph. In this scenario, A is the root node. Node H is the destination node. Packets have to be sent from node H to node A. Node F is the Parent of node H. Now the DODAG construction occurs in the following manner. The node information like root node, destination node, neighbour node, possible path to transfer the packet from destination to root, DIO message, DAO message, DAO-Ack message is stored in the storing mode.

Table 1 contains the information of the neighbour node. Neighbours of node H are nodes G, I, E and F. Neighbour of node I are Node H and Node F. Neighbours of Node F are Node C and Node E. Neighbours of nodes E is F, D, B and C. Neighbours of node C are Node B and Node A. Neighbours of node B are node C and node A. Neighbours of node A are node B and node A.

TABLE 1: NEIGHBOUR NODE INFORMATION

Node	Neighbour Nodes
H	G-I-E-F
I	H-F

F	C-E
E	F-D-B-C
C	B-A
B	C-A
A	B-C

Table 2 shows the available paths from the H – A. Already we know that H is the destination node and A is the root node. Table 2 shows the possible direction from the Destination to the Root node. The list of possible directions is listed in the Table. Out of these possible directions, a single path is selected to route the packet.

TABLE 2: POSSIBLE PATH FROM THE DESTINATION TO ROOT

Possible path From Destination to Root
H-I-F-C-A
H-F-C-A
H-E-C-A
H-G-E-C-A
H-G-D-B-A
H-G-D-E-C-A
H-G-D-E-B-A
H-G-E-D-B-A
H-G-E-B-A

The existing objective functions of RPL have different rank calculation methods. By using the above formulas, the rank values are calculated. Based on the rank values, the path is constructed to transfer the packet. This table gets automatically updated until the transaction is completed. Not only table 2 but all the necessary tables are also updated automatically in storing mode.

Energy

In RPL, energy is considered to avoid node failure. To reconstruct the path, energy is considered as the primary factor to avoid disconnect in the path. This happens when there is a presence of a node with minimum energy in the path. Node with minimum energy may leave the path during the routing or before the routing begin. This may affect the normal routing operation in the RPL protocol which increases the packet loss and decreases the packet delivery ratio. Once the parent selection request is initiated at the parent node, the energy of the neighbour nodes start to get calculated.

$$EC = iE - rE \quad \text{--1}$$

$$Ne = Max\ E - Ec \quad \text{--2}$$

Ec = Energy consumed

iE=Energy at initial stage.

rE = Residual energy of the node

Ne = Node energy

Max E= Maximum energy (100)

Here, in this work, energy is considered to avoid selecting the node with a minimum lifetime. Each node has a different energy level. It is not a must for all the nodes in the network to have the same energy. The main aim of this objective function is to calculate the rank value based on the energy and distance.

The procedure involved in calculating the rank value

Step-1: Root node identifies the neighbour node and updates the neighbour information in the table.

Step-2: Control messages are exchanged between the neighbour nodes (Control messages are sent from root to Destination).

Step-3: Depending upon the scenario, the objective functions are defined. The default object function is ETX.

Step-4: If the Objective function is ETX, then equation one is used. Equation two for HOP, and for the energy-based rank calculation equation three is used.

Step-5: Based on the rank value the path is constructed.

Step-6: After constructing the path, routing starts from Destination to Root (Routing in the upward direction).

Step-7: Until the transaction is complete, the tables are frequently updated by broadcasting the control messages between the nodes in storing mode.

Figure 3 shows all nodes present in the network. Based on the rank value, the path is constructed between the Node H to Node A. Paths H-F-C-A are selected to transfer the packet based on the objective function ETX. Figure 4 shows the path selected to transfer the packet.

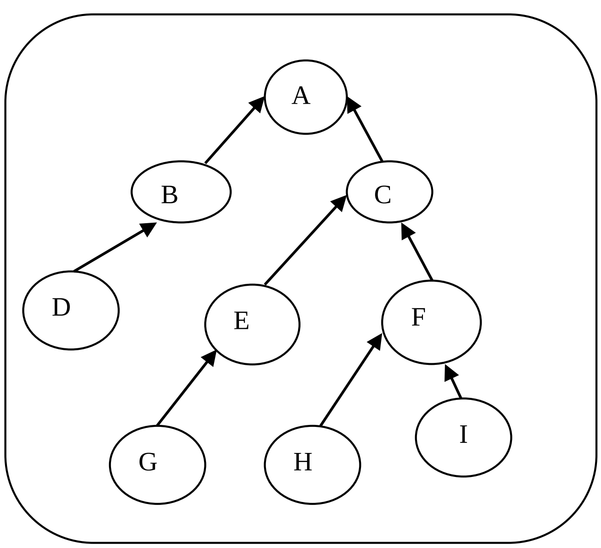

Figure 3: Representation of RPLDODAG

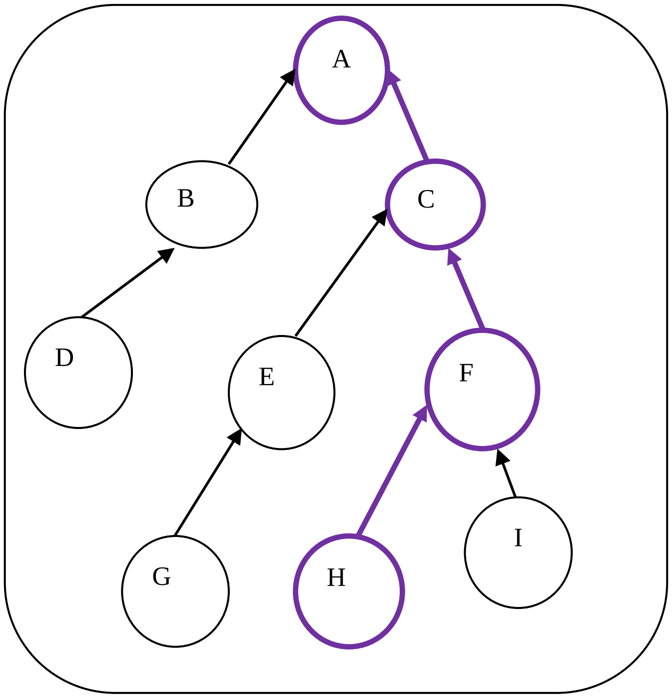

Figure 4: Path selected for packet transfer in RPL- DODAG

Above are all the steps involved in constructing the paths in the DODAG in RPL. These are all the normal steps of the RPL. Some of the issues that are observed during the routing in RPL are Network congestion, Node failure, Energy consumption, Load balancing and so on. In this chapter, an enhanced mechanism is introduced to enhance the performance of the RPL protocol. In general, RPL supports the static nodes in the network. The existing objective function energy-based rank calculation method considers energy as the primary constraint to calculate the rank value. Parents are selected based on the Energy.

This work proposes an approach to enhance the energy-based rank calculation method for RPL. Energy and distance are considered to select the parent in DODAG. A new rank selection technique is introduced to construct the path. In this new calculation method, distance and Node energy are considered for constructing the Path. Distance is calculated by using RSSI. The RSSI value is measured by the amount of signal experienced by the neighbour node. From the RSSI value, distance is calculated. Using the distance value, rank values are computed. Through this proposed work some of the impacts that occur in RPL protocol is overcome. There is an increase in the throughput during the routing from the destination to the root node.

This paper is organized as follows: Section 2 presents the related work. Section 3 explains the proposed technique, computes the minimum neighborhood node that reduces the data transfer delay from source to destination. Section 4 highlights results and discussions. Section 5 is conclusion. Finally, references are cited.

II. RELATED WORKS

Two new techniques were proposed in the research work based on a reactive routing protocol named as Adhoc OnDemand Distance Vector (AODV). [1]Limited mobile nodes play an important role in the routing process among both the newly proposed techniques for reducing the control packets overhead. Either the intermediate node or destination node selects the available energy effective path locally by means of residual energy.

An EAPC (energy-aware path construction) algorithm was proposed in the research study for the selection of approximate set of data collection points, creation of data collection path and also gathers data from the points which possess abundancy of data.[2]The network lifetime was extended through the proposed algorithm and is also responsible for the path cost starting from the existing data collection point to the subsequent point.

The possible futuristic applications of the WSNs were highlighted in the work. [3]Very limited amount of energy and processing power were possessed by the WSNs. But the data transmission over long distance amounts to the major cause of energy consumption. Hence a proper solution was provided to this issue through the developing of energy efficient multi objective criteria clustering technique based on the optimization routing.

An innovative protocol named as Trust Distrust Protocol (TDP) was proposed for the purpose of secure routing of WSNs. [4] Here in the proposed TDP protocol, the routing was performed in four stages. First, k-means algorithm was utilized for topology management. Following in the second stage, the quality of all network node was evaluated using Link Quality Appraisal (LQA). Then in the third stage, grading was performed based on the value of LQA and grade point was allocated to all nodes present in the network. And then in the last stage, the safest path is selected for the routing process based on the grade points.

In [5,] a technique for overcoming node failure in RPL is presented. The energy-aware routing strategy in the network is used to solve node failure in RPL. There are two processes in the proposed technique: determining the node with the shortest lifespan and a parent selection procedure. To improve RPL mobility, the authors suggested a new cost measure that combines the number of hops, RSSI values, and the total of latency in [6]. They also describe the mobile node's movement notification in order to trigger the mobile detection and parent selection operations.

[7] looked through the proposed goal functions and advised that the RPL objective function be improved by taking into account three metrics (load, residual energy, and ETX metrics) rather than just one. [8] offers a hybrid routing protocol based on the routing protocol (RPL) that integrates the two wireless sensing technologies (WSN and MCS) and enables them to communicate with each other. The goal is to employ MCS nodes to support static WSN nodes in an opportunistic manner in order to improve performance. [9] classifies the load balancing methods and goal functions suggested to handle the RPL in Low Power and Lossy Networks load balancing challenge. It also examines the effectiveness of RPL-based routing protocols and objective functions.

The life cycle index (LCI) is proposed by [10] as a route selection objective function. The index considers node metrics (node energy and node hops) as well as connection metrics (throughput, packet loss, and link quality). They also utilize the DODAG structure to suggest a multipath system and use it to address the congestion issue.

RPL's performance is evaluated using three main parameters: network density, throughput, and sink localization in [11]. They also take into account the Expected Transmission Count (ETX), Hop Count (HC), and Energy measures. The authors presented a novel load balancing mechanism called C-Balance based on cluster ranking to boost network lifespan in [12]. For each node, two rankings are determined using this procedure. The first rank is used to identify clusters and cluster heads, while the second rank is utilized to choose parents for each cluster head in order to transfer packets to their destination. Expected Transmission Count, hop count, residual energy, and number of offspring are among the criteria used to compute these rankings.

[13] present CMD, a monitor-based solution to minimize forwarding misbehaviors in LLNs operating with RPL, where one or several malevolent nodes reject any incoming Data packet randomly or purposefully. [14] design and construct a lightweight, trust-based security architecture for mobile IoT network routing. They use conventional security approaches like a nonce identification value, timestamp, and network whitelist to change the RPL IoT routing algorithm. Based on a calculated node trust value and average received signal strength indicator (ARSSI) value across network members, RPL may choose a routing route across a mobile IoT wireless network. [15] focuses on techniques offered in RPL for the load balancing issue.

III. A PROPOSED TECHNIQUE

In RPL, the rank calculation method used to construct the DODAG is framed by considering single primary constraints (Energy, HOP, ETX), which is one of the major drawbacks of the rank calculation method. This approach reduces the performance of the routing protocol. Here, an enhanced energy-based rank calculation method is introduced. Energy- and distance-based parent selection method increases the throughput in RPL. In this work, distance is calculated by using RSSI. From the RSSI value, the distance value is calculated using the formula (3). Through this proposed work, the parents are selected based on the rank value and energy of the node. Node with minimum RSSI value and Node with high energy is selected as the best parent in the network. Node with minimum RSSI value, which means node with minimum rank value, is selected as a parent.

$$\text{Node rank} = \text{Parent Rank} + \text{Rank Increase} \qquad \text{------ (3)}$$

Where
Rank Increase = step + min Rank Increase
Step = max distance - actual distance
Min Rank Increase= 256
Max Distance= 7

Identification of parent node

The proposed work is used to find the nearest node in DODAG. To construct the DODAG, the following steps are involved to construct the DODAG. Based on the distance and energy the nearest node is identified. After calculating the distance from the RSSI value, the energy of the node is calculated. After calculating the energy, the best parent is selected. The node with minimum rank value and node with maximum energy is selected as the best parent.

Working procedure of proposed work

The steps involved in DODAG construction through using the proposed work are explained below.

Steps for DODAG construction using the proposed work
Step-1: Root node initialized with the routing request **Step-2:** Root node starts sending the control message **Step-3:** Rank values are calculated using the formula 6 **Step-4:** Energy values of each node are calculated using the formula 7 **Step-5:** Based on the distance and Energy, the parents are selected to route the packet **Step-6:** Construct the path to route the packet

The steps involved in the calculation of distance based on the RSSI value are listed below.

Distance calculation based on RSSI
Step-1: Child node starts to calculate the RSSI value of the parent node **Step-2:** RSSI value is calculated using the formula Node rank = Parent Rank + Rank Increase **Step-3:** Compute the distance value for the neighbour node

The steps taken for the calculation of energy are given below:

Energy Calculation
Step-1: After calculating the RSSI value of the parent node, the energy of the parent node are starts to calculated **Step-2:** Energy is computed using the formula EC = iE- rE --1 Ne=Max E-Ec --2 **Step-3:** Compute the energy value for the neighbour node

The steps involved in the parent selection method in DODAG are listed below:

Parent selection method in DODAG
Step-1: After calculating the distance and energy **Step-2:** Select the node in Minimum distance and Node with Maximum energy **Step-3:** Continue Step1 to 2 until the routing is complete

In this proposed work, the concepts of RSSI and energy were used to select the best node to route the packet towards the root node. The above steps are framed to avoid node failure due to the presents of a node with minimum energy in the DODAG.

TABLE 3: RANK AND ENERGY VALUES OF THE NODE PRESENT IN DODAG

Node	Energy	Rank
A	91	1
B	76	2
C	83	2
D	90	3
E	81	3
F	76	4
G	81	4
H	84	5

Table 3 shows the energy and rank of the node present in DODAG. The rank value is calculated from the distance value. Distance is calculated by using the RSSI value. Thus, path H-G-E-C-A is selected for routing the packet.

We know that Node E selected Node D as the parent by using the existing objective function. Node E selected Node C as a parent to route the packet. In the existing objective function, energy is considered as the primary parameter. So, Path H-G-E-D-A is selected. In the proposed work, Path H-G-E-C-A is selected to route the packet by considering the RSSI value and energy as primary constraints.

Figure 5 DODAG constructed based on the energy explains that the path H-G-E-D-A is selected to route the packet. This path is selected using the energy-based rank calculation. Node G selects Node E. Node E is the parent of Node G. Parent Node E has two parents Node C and Node D. Rank and Energy of the Node C is 2, 83. Rank and Energy of the Node D is 3, 92. Node C is the parent based on the rank and energy value.

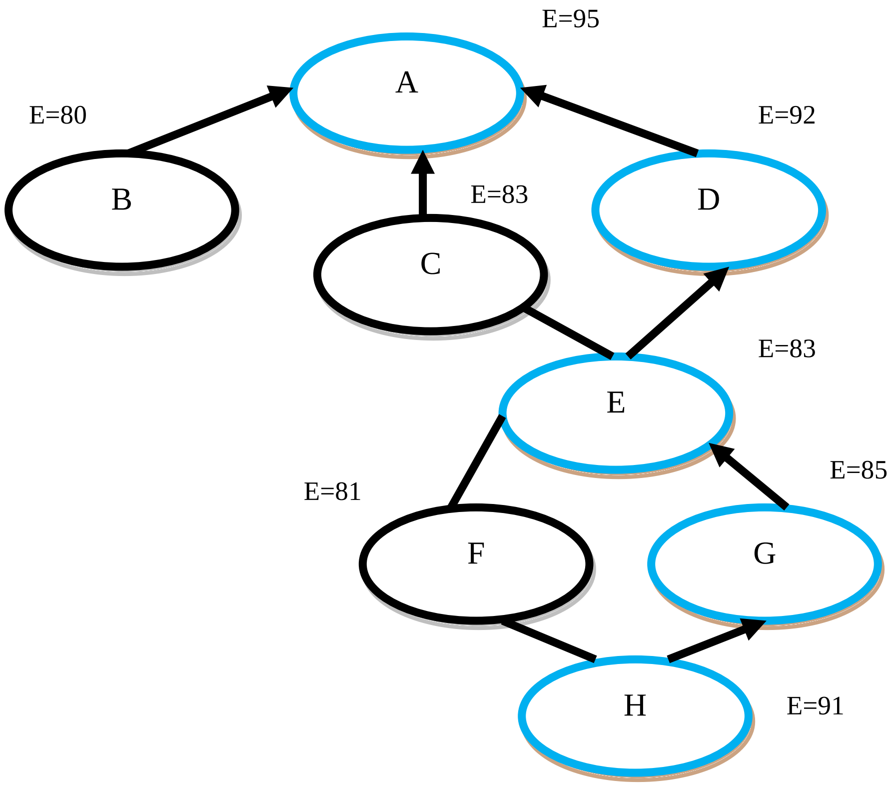

Figure 5: DODAG constructed based on the energy

According to the energy-based rank calculation method, Path H-G-E-D-A is selected to send the packet. Similarly, these steps are repeated until the path is constructed. Figure 6 DODAG constructed based on the proposed work. The path H-G-E-C-A is selected to route the packet.

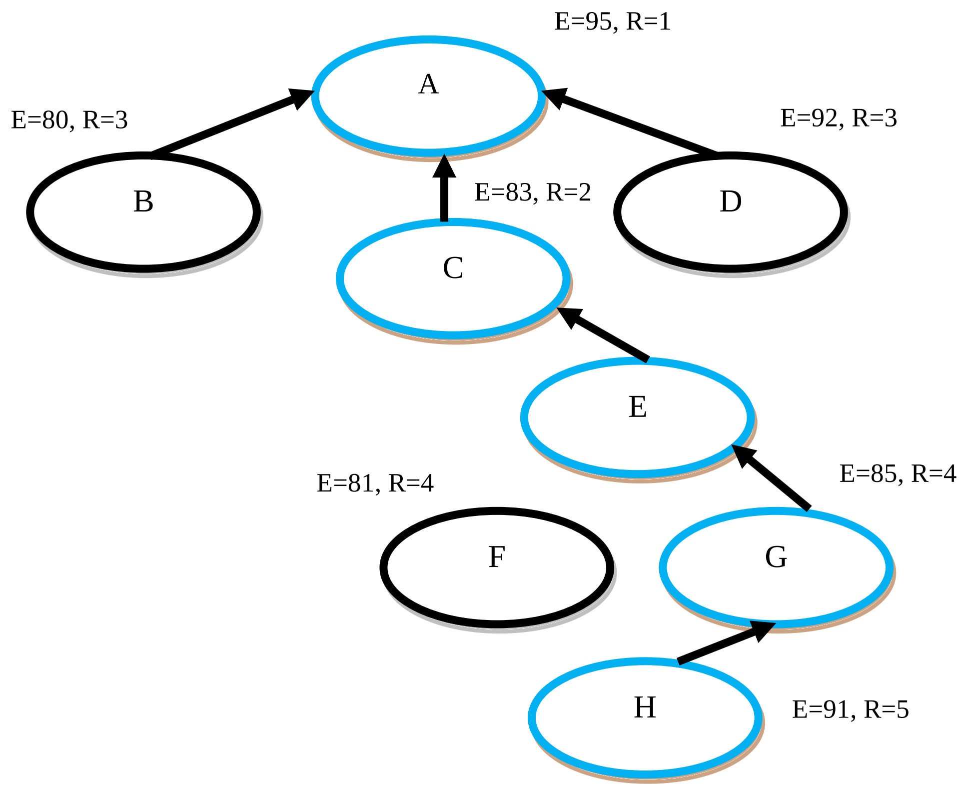

Figure 6: DODAG constructed based on the proposed work

Scenarios and Discussion

Scenario-1

Figure 7: Comparison between existing and proposed work network-1

Figure 7 demonstrates the parent-selection process. In the existing work, Node E selects Node D as a parent. Node E selects Node C as a parent by using the proposed work. This approach increases the throughput in RPL.

Scenario-2

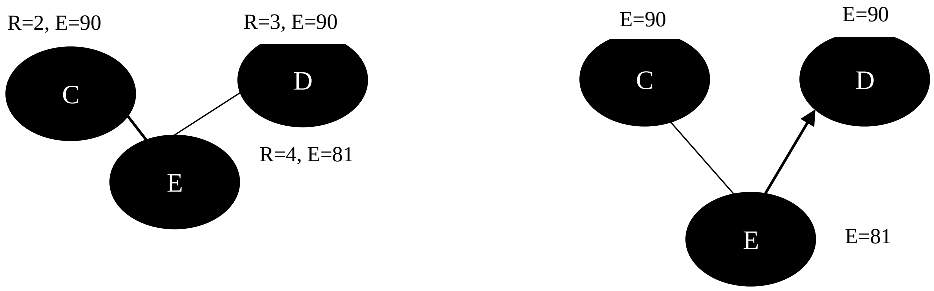

Figure 8: Comparison between existing and proposed work network-2

In scenario-2, Node E selects either Node C or Node D. Here in this scenario, the parent of Node E has the same energy. In this case, this proposed work is used to select the parent. In this case, Node E calculates the Rank value based on the distance. Node E selects the parent by calculating the Rank value and based on the energy of the node. Here, Node C's rank value is 2 and energy is 90 and Node D has the Rank value of 3 and energy level of 90. After validating, Node C is selected to route the packet.

Simulation Procedure

This proposed work is simulated using the Contiki operating system and COOJA simulator. Many simulators are available. Simulators like Network Simulator2, Network Simulator3, J-Sim, Shawn, Glo Mo Sim, Contiki (Scatter Net MSBA2, Mica Z, and COOJA) and so on. NS-3 and COOJA simulators are used as simulators as well as Emulators. In this research work, Contiki Cooja Simulator was used, which is an open-source simulator, in which anyone can simulate their ideas. This proposed work is simulated in IoT real-time environment. The enhanced rank-calculation mechanism is deployed in every node in the RPL network. The parameters that are used to evaluate the proposed mechanism are listed in Table 4 shown below.

TABLE 4: NETWORK SIMULATION PARAMETERS

Parameters	Description
No of Nodes	10,20,50
Simulation Area	700*700m
Data Rate	250kbps
Node Arrangement	Random
Operating System	Contiki
Simulator	Cooja
Types of sensor node	Sky Mote
Packet Analyzer	Wireshark
Techniques	EPS

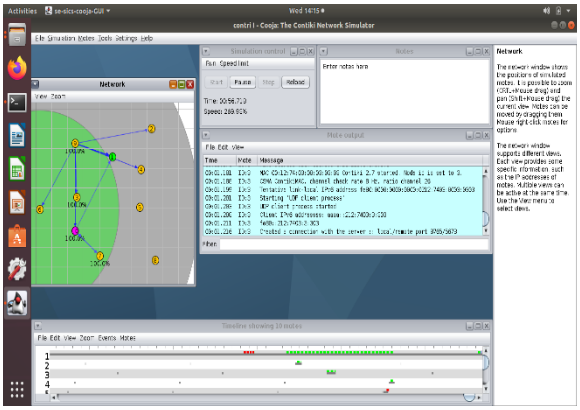

Figure 9: Simulator window with 10 Nodes

Figure 9 shows the Simulator window deployed with 10 nodes. The performance of the proposed work is analyzed with 10nodes. Out of these ten nodes, one sink node, one end node and eight are intermediate nodes.

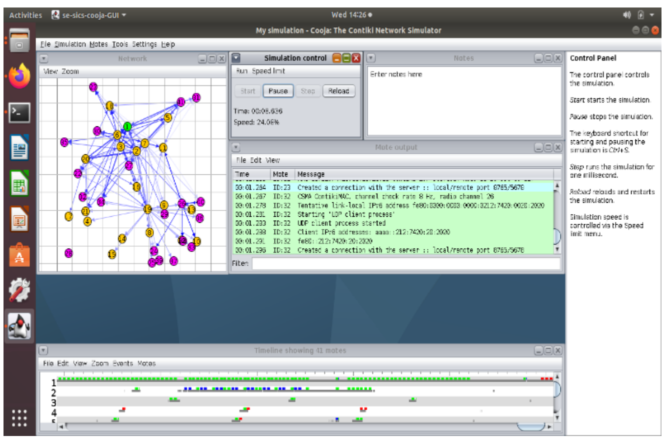

Figure 10: Simulator window with 50 Nodes

Figure 10 shows the Simulator window deployed with 50 nodes. The performance of the proposed work is analyzed with fifty nodes. Out of these fifty nodes, one is a sink node, one is an end node, and forty-eight are intermediate nodes.

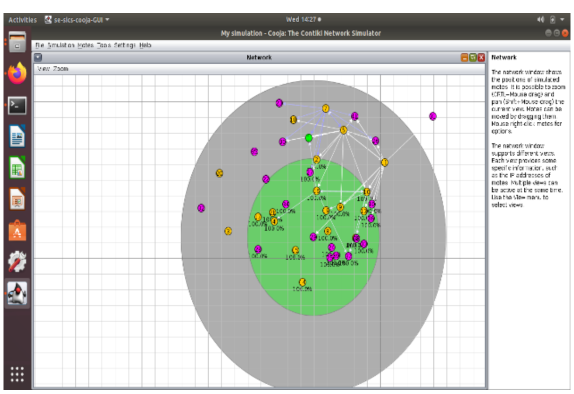

Figure 11: Transmission and Interference range of 50-Nodes

Figure 11 shows that 15 nodes are in the transmission range and 34 nodes are in the interference range and one node is out of transmission and interference range.

IV. RESULTS AND DISCUSSIONS

The metrics used to analyze this proposed work with the existing work are the energy-based rank-calculation method. These two techniques are deployed in the COOJA simulator. Various metrics are used to analyze the performance such as Packet delivery ratio, Packet loss, Throughput, transmission accuracy, Delay, Jitter and so on. Here in this work, throughput is taken to analyze the performance of the proposed and existing work with ten, twenty and fifty nodes.

Throughput

RPL considers throughput as one of the routing metrics. The throughput is a link metric based on the transmission of the packets in the link. Throughput can be abstractly stated as the number of packets multiplied with the size of the packets, divided by the total simulation time in seconds. This generalized formula is formulated due to the subtlety of throughput and the difficulty in measuring them. Throughput is dependent on the traffic workload of the network. The equation for throughput is given below.

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$$\text{Throughput} = \frac{\text{No of the packet sent successfully} * \text{size} * 8}{\text{Total execution time}} \frac{\text{Bits per second}}{\text{Seconds}} \quad \text{-------} (4)$$

The throughput can be calculated by analyzing packet size. The total number of packets transmitted and the total time of the simulation. The throughput value should be more for a network, to be considered better. Table 5 shows the results of the performance proposed EPS and existing method RPL. From the results, we can note in Figure 13, the graphical representation of the variation between the proposed and existing work.

TABLE 5: THROUGHPUT RATIO OF PROPOSED AND EXISTING WORK IN PERCENTAGE

Evaluation	10 nodes	20nodes	50nodes
RPL	92	90.5	89
EPS	90.8	89.1	87.9

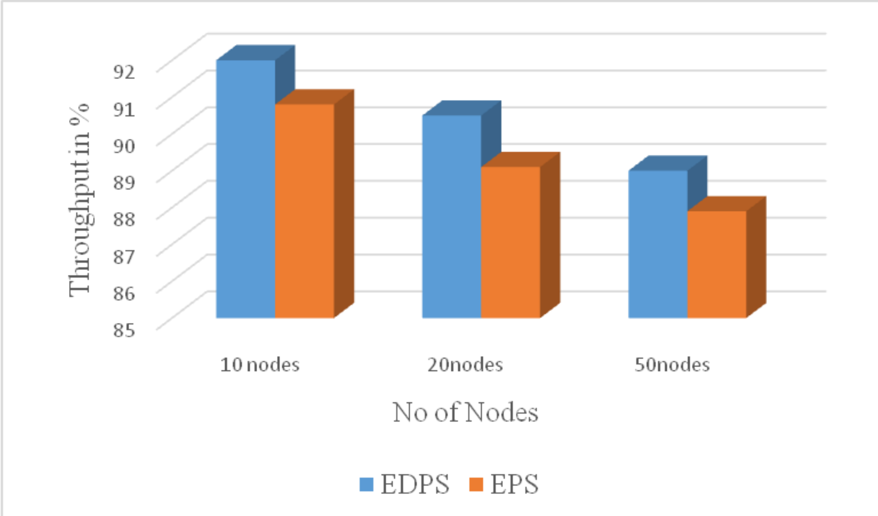

Figure 13: Graphical representation of results

V. CONCLUSION

Energy-aware path-selection process is introduced to select the best parent in the RPL network. In this proposed work, RSSI value and energy are considered as the criteria in selecting the best parent. The node selects the parent based on the rank value and energy. The rank value is calculated by using the concept of RSSI value. Nodes with maximum rank value will have a minimum RSSI value, which implies that the nodes are very close to the child node or root node. The concept of RSSI is used to find the node position and energy is considered to avoid selecting the node with minimum energy. This parent selection routes the packet in a minimal time period. The approach used in the parent selection increases the throughput and decreases packet loss.

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