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Energy Efficient Composite Metric Based Routing Protocol for Internet of Things

Sathishkumar Natesan
(School of Computer Science and Engineering
Vellore Institute of Technology
Vellore, India
nskinfofb@gmail.com)

Rajakumar Krishnan
(School of Computer Science and Engineering
Vellore Institute of Technology
Vellore, India
rajakumar.krishnan@vit.ac.in)

Abstract: The Routing Protocol for Low Power and Lossy Networks (RPL) is operated by gadgets comprised of many devices of embedded type with limited energy, memory as well as resources that do their process. The improvements in the life of the network and energy conservation are the key challenging features in Low Power and Lossy Networks (LLN). Obviously, the LLN has a key strategic part in routing. The Internet of Things (IoT) device is expected to make the apt choice. In LLN, the poor routing choice leads to traffic congestion, reduction in power as well as packet loss ratio. The task in the proposal analyzes Delay (D), Load (L) and Battery Discharge Index (BDI) pivoted Energy Efficient Composite Metric Routing (EECMR) protocol for LLN. The performance of the work in the proposal is evaluated by the COOJA simulator. It outperforms with respect to Network Lifetime (NL), Delay as well as Packet Delivery Ratio (PDR) contrasted to the routing metrics like Traffic Load (TL), Link Quality (LQ), Residual Energy (RE), RE-Battery Discharge Index (RE-BDI) and Hop Count (HC).

Key Words: Energy efficiency, Load, Internet of things, Residual energy
Category: H.3.4, H.3.5, C.2.2

1 Introduction

The networks of the Internet of Things (IoT) are found normally in a distributed way. The devices of IoT have every possibility to be moving most of the time. The mentioned device will be on the lookout to find the neighbor if any in the vicinity [Sennan et al.2019]. This act of stated device is termed as neighbor discovery. The gadgets of IoT with limitations on their capacity of the battery throw challenges in designing a neighbor discovery protocol [Sankar and Srinivasan 2018]. Since the latter must have a small duty cycle as well as a small discovery latency [Shen et al. 2019]. At the IoT's sensor layer there is a vast number of sensor nodes deployed in a dense way in an environment that is hostile. Care must be exercised to sense the changes physically in that space as well as to monitor them. The batteries at sensor nodes have a small power, it is found costly as well as cumbersome for Wireless Sensor Networks (WSNs) to stretch the life of networks [Xu et al. 2019].

To ensure transmitting data in WSNs to be efficient the protocol for routing must conserve energy to extend the stated life. The conventional protocols for routing generally do propagate throughout the entire network. To identify a route to be reliable or introduce cluster heads to help to transmit data to the rest of the nodes again cause extra energy dissipation [Tian et al. 2015]. The IoT in industrial applications must be much more efficient from the point of view of the dispatching of data. A protocol for routing named Network Coding and Power Control based Routing (NCPCR) is utilized for wireless networks in places having more dissipation of energy. In the routing protocol, a child node basing on the rank value selects a parent node [Singh and Chen 2019]. IoT improves in modern times in RFID, smart sensors, Internet technologies as well as protocols for communication. Sensor nodes are recognized as smart devices popularly utilized to transfer information. But, there are many constraints on them since they are prone to security attacks [Haseeb et al.2019]. Of late, many applications of IoT have emerged. The basic need here is mobility. The moving mobile node near the application domain affects the IoT's Routing Protocol for Low Power Lossy Network's (RPL) functioning. It causes disruptions frequently leading to loss of data as well as increased dissipating of power [Sanshi and Jaidhar 2019].

In the near future, 5G as well as applied domains of IoT are relying much on transmission technology meant for distant ranges like networks of a low-powered type with wider-area. To be specific, one can state that the physical layer of LoRa on which LoRaWAN is built. This has drawn the increased focus on it by academia as well as firms, to encourage economically viable WSN of IoT which have better energy efficiency. To cite an example, wide area environmental monitoring. The range of communication will increase to 20 km. But, the bit rates achieved in LoRaWAN have a limiting rate up to a few kilobits per second. When collisions occur, the rate is reduced as there is packet loss as well as retransmissions [EI Rachkidy et al.2019]. The major challenge experienced now is the dissipation of energy for gadgets of the wireless network. Energy harvesting promises to come to the rescue in providing power to the IoT. In the communication stack's layer of Medium Access Control (MAC) the stated harvesting introduces spatial as well as temporal uncertainties in the available energy[Fafoutis et al. 2015].

The recent mushrooming of IoT in many environments that are security-sensitive makes the security at such networks as a concern. In many networks of IoT routing is done utilizing RPL, as it is having secure modes availability, energy efficiency mechanisms as well as its adaptivity to function in different situations. This is the reason RPL security is focused on several researchers now [Raoof et al. 2018]. The dissipation of energy is one of the parameters of concern in the market of IoT's sensor systems now. Even the sensor systems meant for the long-range are not an exception. As the application is in the environment of outdoor, the mechanisms of harvesting energy can be combined to have the benefits of low power. The use of electric components of low power alone will not serve to ensure energy efficiency [Purkovic et al. 2018]. IPv6 RPL is a standard protocol of routing for the networks of energy-constrained types in the networks of IoT. Now, several applications in real-time expect support in mobility among the nodes in RPL with speeds of varying range. To support mobility in RPL is an issue of a critical challenge now as the devices have constrained resources. Moreover, the links for communication are lossy to establish a stable network. The overhead for the control packet will increase fast when in motion. This consumes extra energy ultimately the network's life is reduced [Murali and Jamalipour 2018].WSNs have a wide range of applications in various fields. The recent applications are in the field of IoT. It is allowing inter-connecting of various gadgets through the internet. But, the limitation on battery power is the WSNs' primary concern as unlike ad-hoc networks of mobile type, the network's life is affected [Behera et al. 2018].

Hence, much research is directed towards minimizing the WSNs' energy dissipation. While the node of participant type wants a joining in Destination Oriented Directed Acyclic Graph (DODAG), considering the parameters of battery discharge, free from loops, link quality as well as traffic load and such others. The proposal is introducing load, delay as well as battery discharge index (BDI) centered routing metric of composite type in RPL. At regular intervals, DODAG is sending the messages of DODAG Information Object (DIO) towards every participant node. The mentioned node is choosing the parent that is possibly the best from the rank of DODAG. The rank is calculated from the node's minimal load as well as the values of BDI. Then the participant node is selecting the best parent node from DODAG. This is the way it is reducing the data traffic of multipoint-to-point type in upward routing. It is avoiding the nodes to create a hole in the network by way of depleting the battery as well as decreasing the ratio of packet loss.

2 Related Works

[Nguyen et al. 2018] proposed the design of a routing protocol for energy-harvesting-aware for IoT with networks of heterogeneity when the energy sources were present in the neighborhood. A fresh Energy-Harvesting-Aware Routing Algorithm (EHARA) was proposed. It improved it further by integrating a fresh term known as “energy back-off”. By the combination of various methods of energy harvesting, the proposed algorithm improved the nodes' life as well as the quality-of-service (QoS) of the network under varying load traffic as well as conditions of availability of energy. In addition, this work also analyzed the metrics of system performance under various conditions of energy harvesting. The results of its functioning demonstrated the EHARA in the proposal is an energy-efficient one. At the same time, it satisfied the requirements of QoS of distributed networks of IoT compared to the protocols of routing in existence. [Lee et al. 2018] analyzed the techniques of split power kind of exchanging of energy utilizing the methods of transferring energy in the Radio Frequency (RF) range. The fresh method was a proposal known as Wireless Information and Power Exchange (WIPE). In the latter method proposed, every node operated either in a transmitting or a receiving mode at every slot of time. In other words, the receiving node in the prior slot of time now operated in a transmit mode and it transferred signals of RF by utilizing the energy harvested.

[Sankar and Srinivasan 2017] proposed introduced the load as well as Battery Discharge Index (BDI) pivoted routing metric of composite type in IPV6 RPL. The simulator COOJA was utilized for evaluating the functioning of the work proposed. It provided the better result as far as the life of the network as well as packet delivery ratio (PDR) against the metric for routing like ETX, hop count, RER, traffic load as well as RER (BDI). [Kumar and Kumar 2019] proposed a collision aware priority level mechanism pivoted on the medium access control protocol (CAPL-MAC) to do data transfer to the SN from the sensor head (SH). The protocol in the proposal utilized a parallel competition scheme (PCS) to do more usage of a channel as well as conserving the battery's power. Pivoted on the highest PLN, every SH communicates to SN is avoiding a collision. It reduced also propagation delay and had better timing efficiency. Ultimately, QoS was better too. The simulating method used Aqua-Sim Network Simulator 2 (NS2). The results of the simulation had shown that the CAPL-MAC protocol proposed realized the prior mentioned functioning better compared to the present protocols like competitive transmission-MAC (CT-MAC) as well as channel aware aloha (CAA).

[Kim et al. 2017] analyzed the following research history of pursuits in RPL: 1. The aspects that were (those which were not) studied. 2. In addition, they were evaluated 3. The way they were analyzed. 4. That which were (those that were not) implemented. 5. Finally, that remained for further analysis. Nearly 97 RPL-associated research works published by main academic journals were reviewed. Then presented a survey that was topic-oriented for such research pursuits. The survey undertaken indicated 40.2% of the works only evaluated RPL by way of experiments implemented on real embedded gadgets. ContikiOS as well as TinyOS were a couple of the most widely held implementations (92.3%). Next, TelosB was the most frequently utilized hardware platform (69%) on test-beds that had average. Further, there was a median size of 49.4 as well as 30.5 nodes, respectively. Nearly four years after its initial standardizing, RPL was yet to be adopted widely as part of systems as well as applications in a real-world scenario. The observations were presented on the reasons behind that as well as directions were suggested on which RPL must be evolved.[Biason et al. 2017] described a context-aware as well as energy-centric optimizing infrastructure that would account for the impact of energy of the IoT's basic functionalities of a system. It proceeded along with three primary technical driving aspects: 1) maintaining the balance of signal-dependent methods of processing (compression as well as extraction of feature) as well as tasks of communication; 2) to design in a joint way accessing of a channel as well as protocols of routing for maximizing the life of network; as well as 3) to provide self-adaptability for various conditions of operation by adopting proper learning architectures as well as flexible/reconfigurable algorithms as well as protocols.

[Correia et al. 2017] proposed the usage of constrained RESTful environments interfaces for building collections of resources that might increase the life of a network. To be specific, centered on the atomic resources that exist, the collections were either created or designed so that they became available as fresh resources and these could be observed. The designing of these resources should match the interests of the customer. Added to that increase life of network as far as possible. To realize this dissipation of the energy it should be balanced/fair among nodes such that depletion of the node was delayed. Comparing to the methods prior to that, results showed that the efficiency of energy as well as the life of the network could be increased at the same time reducing the messages that control/register, which was utilized to set up or change the observations. [Zhao et al. 2016] proposed a new Energy-Efficient Region-Based Routing Protocol (ER-RPL), achieving delivery of data that is energy-efficient with no sacrifice on the reliability. Unlike conventional protocols for routing where every node was expected to do discovery of route, the method in proposal needs only nodes' subset to do the task, which is vital to save energy. They theoretically analyzed as well as conducted studies of simulation extensively as well as demonstrated that ER-RPL excelled over a couple of traditional protocols of benchmark, that is, RPL as well as P2P-RPL.

[Kim et al. 2019] proposed a simple but effective Queue Utilization-based RPL (QU-RPL) that achieved load balancing as well as improved significantly the end-to-end performance of delivery of packet compared to the RPL of standard type. To every node designing of QU-RPL is done for selecting its parent node. The queue of the respective nodes of the neighbor as well as their hopping distances to an LLN border router (LBR). It was due to its capability of load balancing, QURPL is much effective in reducing losses of the queue as well as increasing the ratio of packet delivery. The QU-RPL was implemented on a low-power embedded platform. The verifications were done on a test-bed in a real-time scenario situated in a multi-hop LLN in line with the standards of IEEE 802.15.4. The effect of design aspects of QU-RPL over their functioning was presented. Finally, QU-RPL was diminishing the loss due to queue became 84% as well as improved the packet delivery ratio reaching 147% in comparison with the RPL of standard type. [Correia et al.2016] addressed by the utilization of interfaces of CoRE for the design of the resource. Such interfaces permitted the server to compose/organize resources as well as the customer for discovering. Then found out ways to consume those resources. This was apart from permitting decisions to be integrated easily into the network's operation. A model of energy-aware resource design was proposed, centered on interfaces of CoRE, to design resources to suit the requirements of customers. The stated model was the base, for developing an algorithm that had better energy efficiency.

[Liu et al. 2019] envisaged realizing energy-efficient as well as greater performance in monitoring, an efficient method of Knowledge-aware Proactive Nodes Selection (KPNS) was the proposal here. The innovative aspects of KPNS: 1) the nodes of the proactive type's count's dynamic adjustment were made based on the prediction accuracy of the trajectory of the target. In case the accuracy of prediction was large, the count of nodes of a proactive kind in the area predicted was not the main area it would decrease. [Bouaziz et al. 2019] Here, novel energy-efficient as well as mobility aware routing protocol in a proposal known as EMA-RPL referring to the well-known RPL. The static devices supported by the RPL relatively consume considerable energy. In mobile nodes, EMA-RPL sustains better connectivity, added to that it conserves energy.

[Natesan and Krishnan 2020] put forth a routing protocol for a multi-layer fuzzy logic cluster-based power-efficient. Each ring was divided into clusters of equal-size by the intra-ring clustering scheme. The simulated outcome inferred that it attained better packet delivery ratio, power efficiency, throughput as well as the life of the network.

[Lin et al. 2018] made a proposal about the implementation of an IPv6 utilizing development boards of Raspberry Pi 3 a nRF51-DK. Next, the message queuing telemetry transport (MQTT) for sensor networks protocol as well as the Constrained Application Protocol (CoAP) were run across the IPv6 protocol stack. To be specific, in their experimenting system each Bluetooth Low Energy (BLE) node is IPv6-accessible as well as addressable via the protocols of MQTT/CoAP from any point across the Internet.

[de Souza et al. 2018] the prime supportive aspect of their work is the proposal of an architecture that is of a distributed kind for IoT. It is known as context awareness in the internet of things. The design of this architecture is to offer the interactions to manage in a proactive way with the physical situations. The architecture in the proposal's performance was weighed by a case study implementation in the domain of agriculture.

[Alulema et al. 2018] designed the architecture of cross-device type to integrate the technologies as well as implementations in homes. It was also utilized as a basic security process. The evaluation of the proposed cross-device was carried out by designing a case study situation. It included as well as integrated Smart Phones, digital-TV and for monitoring clients' physical activity by means of wearable devices provided to them.

The protocol in the proposal was integrating a technique of enhanced mobility detection by way of control of continuous type by controlling the distance from the mobile node to its attachment. It was a new way of predicting attachment basing on the mobile node's location that was different. Also, it was a method of efficient replacement where the mobile node's energy was preserved. It surmounted the hump of EMA-RPL as well as mitigated the issue caused by the nodes' mobility. The Cooja/Contiki's simulated results showed that EMA-RPL excelled in the RPL as well as its mobility aware variant (MRPL) as far as the rate of data loss, delay in the handover, and cost of signaling as well as dissipation of energy.

3 Proposed Routing Metric

In IoT, the challenges faced by routing protocols for low power and lossy network (LLN) like unreliable wireless links, lack of infrastructure and constrained resources. Due to the traffic overhead and multi-hop routing, the lifetime of the network is reduced. To address the issues mentioned above, the proposed model advocates the routing metric which is of energy-efficient type with composite nature. Now the network has a longer life. It creates a better route. The path is represented as:

$$P_x = N1 + N2 + ...N_n \tag{1}$$

Here Px belongs to ; traversed nodes are N1, N2, N3 • • •, Nn. Every node is linked to delay, battery discharge index as well as load in the network.

3.1 Load

The traffic during data dispatch through a network is a measure of data amount in a specific period. One of the metrics is the load which utilizes the balancing of the data traffic. The load is computed pivoted on the available children's count in the parent node. The DODAG's node telecasts DODAG Information Object (DIO)'s information to every node that participates in it. The node of the sender or participant computes the number of children for every parent node preferred. Ultimately, the rank is generated by DODAG by looking at the path for the availability of the cumulative number of children. The participant node has a couple of tasks to do: first, the parent is selected from their preferred list.

Obviously, as stated earlier the next job is the discrete choice of the Load. The Additive kind of property is followed by the metric Load. The computation of traffic load is done according to Eq. (2) as well as Eq. (3).

3.1.1 Load Calculation

Computation of the Path Load (x) depending on child set or cumulative traffic at node:

$$L_{Px} = \sum_{n=1}^{n} NT(N) \tag{2}$$

Where L is Load NT is Node Traffic

To compute the traffic at node depending on the children's cumulative number.

$$NT(N) = \sum_{i=1}^{n} CC(i) \tag{3}$$

Where CC is the children cumulative NT is the node traffic

Algorithm 1: The load-balancing algorithm is below

1: Input: Received-DIO [Version Number,InstantID, ParentID,Rank, RankID]
2 begin
3: DIO $\rightarrow ParentNode$;
$4 : DAO \rightarrow SenderNode$;
$5 : while\, Parent\, Node\, ID = Sender\, Node$
$Prefered\, Parent\, ID$
do
$6 : Children - set++$;
$7 : end$
$8 : while\, the\, Cumulative\, number\, of\, children\, checks\, by\, Sender\, Node\, of$
$Prefered\, Parent\, Node\, do$
$9 : if\, it\, is\, the\, least\, cumulative\, number\, of\, children$
$then$
$10 : Add\, DODAG\, to\, Sender\, Node$
$11 : else$
$12 : The\, preferred\, parent\, Node\, discards\, by\, the\, Sender\, Node$
$13 : end$
$14 : Broadcast\, DIO\, after\, updating$

In algorithm1, the different inputs are considered such as version number, parent id and rank id. The next step is when Destination IO message is sent to each parent node, at the same time DODAG Advertisment Object (DAO) message is sent to every sender node. If the parent node id is the same as the sender node preferred parent id then the children node's count is advanced by number one. The next step is the sender node preferred parent id will check the cumulative number of the children. If it were to be the least of the cumulative number of children, then add the DODAG to the sender node. Otherwise, the preferred parent node is discarded by the sender node. Finally, the broadcasting of DIO is done after updating it.

3.2 Battery Discharge Index (BDI)

From the residual energy, BDI is derived. Such energy is calculated from every RER's node (Ni). By knowing the initial as well as current energy, that energy is computed using the formula given in Eq. (4).

$$RER_{Ni} = EC/EI \tag{4}$$

Where EC- Current Energy EI- Initial Energy The BDI is calculated for the node

$$BDI_{NI} = 1 - RER(Ni) \tag{5}$$

The Path's BDI Px computation is done using Eq. (6). It follows the product rule.

$$BDI_{Px} = \prod_{i=1}^{n} BDI(Ni) \tag{6}$$

Where BDI is the Battery Discharge Index

3.3 Delay

The transit time as it moves away from a node towards the DADOG root is known as Delay in the protocol of RPL

$$AD = AD_{cp} + D_P \tag{7}$$

where AD stands for the averaged delay declared by a Candidate of Parent (CP) D denotes the delay of forwarding from the node to its CP.

3.4 Objective Function (OF)

The OF is defining the way for selecting the node of DODAG as well as optimizing the route in the RPL instance. The OF basing on the composite metric proposal is for enhancing the efficiency of energy. It focuses on the problems like the bottleneck nearer to the sink node, data traffic in the communication of multipoint-to-point and the free situation at the loop. The OF is expressed in Eq. (8). So, the two metrics get equal preference. It is applying varied values of weight during simulating step and setting the values of w1 as well as w2 and W3 both to be 0.5 was found to be a satisfactory condition.

$$minof_{LE}(BDI, LB) = W1XL(Pi) + w2XBDI(Pi) + w3XD(pi) \tag{8}$$

3.5 Calculation of Rank

The computing of rank is based on the rank increase as well as parent rank. The rank increase is calculated using the step as well as MinHopRankIncrease. 256 is the value, by default for the MinHopRankIncrease [Sankar and Srinivasan 3017]. The computation of step value is done by OF. Then the scalar value is returned by it. The formulas for computing rank are given in eq. (9) as well as eq. (10).

$$R(N) = R(PN) + RI \tag{9}$$

$$RI = S + MHRI \tag{10}$$

‘ Where R is the Rank RI is the RankIncrease S is the Step Value MHRI is the Minimum Hop Rank increase

3.6 Parent Selection Process

The algorithm shows the process of selecting the parent is given as follows:

Algorithm 2: Selection of Parent

1:Input: BestParent-Rank=, Participant Node-Parent ID,
Parent-Node ID, Node N
2: Output: Preferred-Parent (PP)
3: for
4: PP Parent-List do
5: Rank(R) ← Rank increase + Rank(PN)
6:Rank-Increase ← MinHopRankIncrease + Step
7: Step$_Values = L(Pi) * w1 + BDI(Pi) * w2 + Delay(Pi) * w3$;
8 : $IfBest - Parent - Rank >= Prefered - Parent - Rank(PPR)$
9 : $ThenBestParent_Rank¸PPR$;
10 : $endif$
11 : end
12 : $While PPR = Best - Parent - Rankdo$
13 : $Participant - Node - Parent - ID¸Preferred - Parent - Node - ID$
14 : End

The node of DODAG is sending periodically the DODAG Information Object (DIO) towards every PPN. The PPN wishes to do data dispatch through the next possible node and finally ending up in root. The choosing of the preferred parent in DODAG is a must. The possibly best parent is selected from the DODAG's rank.

The work in proposal introducing Load, composite metric basing on BDI as an OF as well as it is giving equal preferences to a couple of the metrics. The load metric is following the property that is additive while BDI is following the property of productivity. When selecting the parent, the PPN is preferring the minimum value of the DODAG is enabling the timer of the trickle. The size of the present interval (I) is ranging between Imin and Imax. In general, the protocol of RPL's values of default is Imin is 12 ms as well as Idoubling is

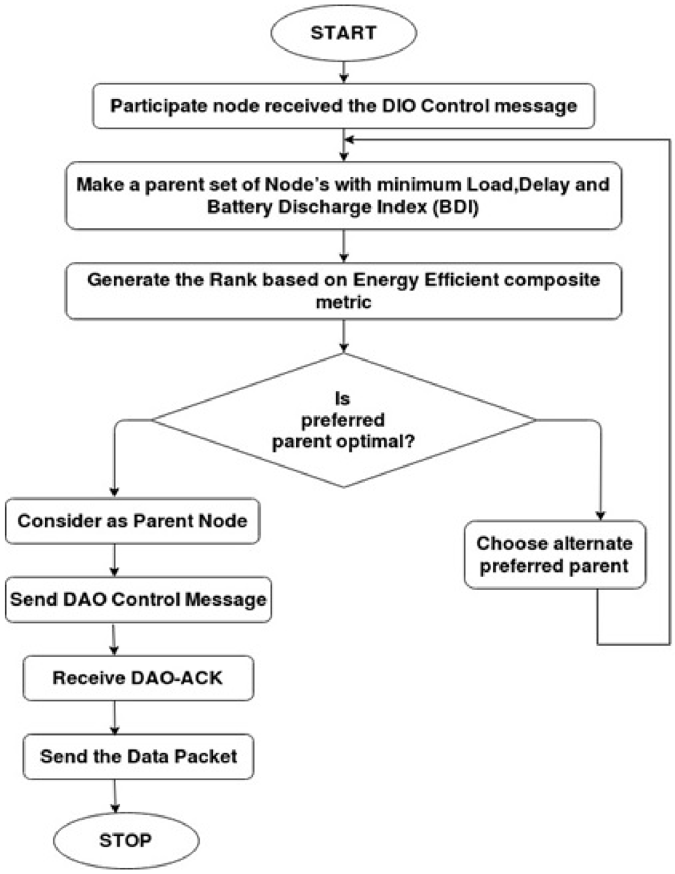

Figure 1: Selection of parent and data sending mechanism

10ms. Prior to dispatch of the message of DIO, the counter for trickle time c is initializing to be zero. Then it is starting to dispatch the messages of DIO to nodes of neighbor. DODAG is expecting from PPN, the messages of DODAG Advertisement Object (DAO). The DODAG is extending the interval "I" from Imin to Idoubling, whenever the trickle time is expiring. In case the expiry of the trickle timer occurs once more, obviously that control signal is absent. Next, the trickle time gets reset by the node of DODAG. Afterward, PPN sends the control signal of DIO to every PPN. The DAO is sent by PPN to DODAG. The latter is sending the DAO- Acknowledgement (DAO-ACK) towards the PPN. The layer of MAC is sending the DODAG-ACK to PPN.

In algorithm2, the various inputs are considered such as BestParent-Rank=, Participant Node-ParentID, Parent-NodeID and Node N. The output is Preferred Parent(PP). The next step is to check whether PP is on the parent list. Then rank is calculated with the rank increase along with the rank of the parent node. The step value is found using battery discharge index, delay and load.

Next, the rank increase is computed with Min-Hop-Rank-Increase together with the step value. After that in case, the Best Parent Rank(BPR) is greater than Prefered Parent Rank (PPR), then the PPR is assigned to BPR. Finally, when PPR is equal to BPR then Participant-Node Parent ID is assigned from Preferred parent node id.

4 Results and Analysis

Table 1: Experimental set up for simulation

Simulation Parameter	**Values**
Operating System	Contiki OS 2.7
Type of Node	Tmote Sky
DIO's Mini Interval	13
Protocol of Routing	RPL
Number of nodes	100 RPL routers and 1 DODAG root
Adaptation layer / MAC	6LowPAN /ContikiMAC
Radio environment	Unit disk graph medium
Count of Nodes	30 Nodes
Duration of Simulation	24 Hour
Full battery	3000 mA
Range of transmission	$400 \times 400\ m^2$
Packet timer of data	60 sec
Parameter of RPL	minHopRankIncrease=256

The work in the proposal is enhancing the aspects of RPL standards. It evaluates the functioning with respect to the packet delivery ratio as well as the life of the network. The COOJA network simulator is utilized to conduct the simulations [Sankar and Srinivasan 2017]. Contiki is an open-source operating system. Its design, in particular, is made for IoT. It is supporting 6LoWPAN, IPv6, RPL and such others. It is providing the small powered transmission for gadgets which have notable constraint resource. The medium of a wireless type that is of lossful natured one's simulation is done utilizing the graph model of unit disk present in the simulator of COOJA. During the simulation, the protocol of RPL did support the traffic of the multipoint-to-point type from the sender node to the root of DODAG. The simulation parameters are presented in Table-1 The standard mechanism of the radio duty cycle is utilized at the layer of MAC [Bouaziz et al. 2019]. For analyzing the functioning of the work in the proposal against existing OF like Link Quality (LQ), Traffic Load (TL), Residual Energy (RE), RE-Battery Discharge Index (RE-BDI) as well as Hop Count (HC) with the values of weight w1 as well as w2 is 0.5. The functioning of the work in the

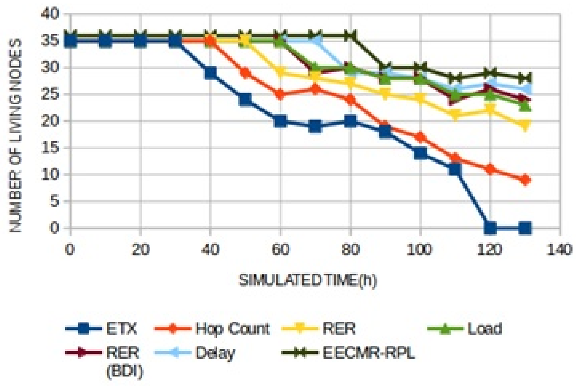

Figure 2: living node's count vs. simulation time

proposal is gauged by the life of the network as well as the Packet delivery ratio. The details of the life of the network as well as packet delivery ratio are narrated below:

4.1 Network Lifetime

This is a criterion that is noteworthy to evaluate the routing protocol efficiency for a gadget with resource constraints [Sankar and Srinivasan 2017]. It is simulated as well as nodes' count is assumed to be 45. The experiment is conducted based on the living node's count at a specified time instant. If the current residual energy in a node is less than 5% it is deemed as a node not-alive. EECMR-RPL is maintaining the battery in the 'top-up' condition for 70 hours. Then in a gradual manner the battery discharges. By the end of a simulating period of 140 hours, 25 nodes of the network are found to be alive. Maintaining the same simulating time, the comparison of living node's count is with varied metrics is done. The simulated period in hours is shown on the X-Axis. The living nodes' count is represented as Y-Axis. The simulating experiments are done.Fig.3 depicts the node of the living type's count versus simulated time. The EECMR-RPL in the proposal possesses an enhanced life of the network.

4.2 Packet Delivery Ratio

The packet delivery ratio indicates the data packets' count was successfully collected at the destination from packets' count sent by the sender. Otherwise, the successful collected data packets' ratio with the entire dispatch. X-Axis stands for Transmission Speed (TS) while Y-Axis represents the packet delivery ratio [Kumar and Kumar 2019]. The Transmission Ratio (TR) is cent percent and the receipt ratio (RX) is checked for varied input. This leads to EECMR-RPL functions better at higher values of RX. In turn, the ratio of packet loss lowers during higher values of RX. The metric in the proposal is having a minimal packet loss ratio in the entire values of RX. The average packet delivery ratio of

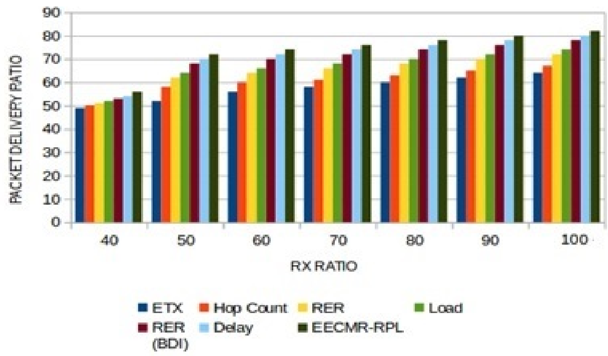

Figure 3: Average number of parent changes

EECMR-RPL is greater than 80% of the values of RX ranging from 80 to 90. Fig.3 depicts the work in the proposal (EECMR-RPL) packet delivery ratio is as shown below.

5 Conclusion

The value of rank is computed from the composite routing metric. The proposed work's performance is assessed by way of PDR as well as the life of the network. The outputs of experiments infer that the system in proposal yields improved functioning containing a small Packet Loss Ratio as well as betters the life of network compared to the OF existing in Traffic Load (TL), Link Quality (LQ), Residual Energy (RE), RE-Battery Discharge Index (RE-BDI) as well as Hop Count(HC). Hence, the work in the proposal realizes the bettered life of the network (25 nodes are found alive after the simulation of 130 hours). Also, the packet delivery ratio goes on with an increasing trend with respect to the value of RX. In the near future, it will be inclusive of the link metric such as Received Signal Strength Indicator (RSSI) as well as the fuzzy parameter-based routing decision-making be applied to it in LLN. Load, Delay as well as the protocol of BDI based Energy Efficient Composite Metric Routing (EECMR-RPL). In RPL, the PPN wishes to dispatch the packets of data by way of the parent node to the root of DODAG. The latter selects the best possible parent node available at DODAG using the rank. Now it is the preferred parent.

References

[Alulema et la.2018] Alulema, D., Criado, J., Iribarne, L. (2018). A Cross-Device Architecture for Modelling Authentication Features in IoT Applications. J. UCS, 24(12), 1758-1775.

[Behera et al.2018] Behera, T. M., Samal, U. C., Mohapatra, S. K. (2018). Energy-efficient modified LEACH protocol for IoT application. IET Wireless Sensor Systems, 8(5), 223-228.

[Biason et al.2017] Biason, A., Pielli, C., Rossi, M., Zanella, A., Zordan, D., Kelly, M., Zorzi, M. (2017). EC-CENTRIC: An energy-and context-centric perspective on IoT systems and protocol design. IEEE Access, 5, 6894-6908.

[Bouaziz et al.2019] Bouaziz, M., Rachedi, A., Belghith, A., Berbineau, M., Al-Ahmadi, S. (2019). EMA-RPL: Energy and mobility aware routing for the Internet of Mobile Things. Future Generation Computer Systems, 97, 247-258.

[Correia et al.2017] Correia, N., Mazayev, A., Schütz, G., Martins, J., Barradas, A. (2017). Resource design in constrained networks for network lifetime increase. IEEE Internet of Things Journal, 4(5), 1611-1623.

[Correia et al.2016] Correia, N., Schütz, G., Mazayev, A., Martins, J., Barradas, A. (2016). An energy-Aware resource design model for constrained networks. IEEE Communications Letters, 20(8), 1631-1634.

[de Souza et la.2018] de Souza, R. S., Lopes, J. L., Geyer, C. F. R., Cardozo, A., Yamin, A. C., Barbosa, J. L. (2018). An Architecture for IoT Management Targeted to Context Awareness of Ubiquitous Applications. J. UCS, 24(10), 1452-1471.

[EI Rachkidy et al.2019] El Rachkidy, N., Guitton, A., Kaneko, M. (2019). Collision resolution protocol for delay and energy efficient LoRa networks. IEEE Transactions on Green Communications and Networking, 3(2), 535-551.

[Fafoutis et al.2015] Fafoutis, X., Di Mauro, A., Orfanidis, C., Dragoni, N. (2015). Energy-efficient medium access control for energy harvesting communications. IEEE transactions on consumer electronics, 61(4), 402-410.

[Haseeb et al.2019] Haseeb, K., Islam, N., Almogren, A., Din, I. U., Almajed, H. N., Guizani, N. (2019). Secret sharing-based energy-aware and multi-hop routing protocol for IoT based WSNs. IEEE Access, 7, 79980-79988.

[Kim et al.2019] Kim, H. S., Kim, H., Paek, J., Bahk, S. (2016). Load balancing under heavy traffic in RPL routing protocol for low power and lossy networks. IEEE Transactions on Mobile Computing, 16(4), 964-979.

[Kim et al.2017] Kim, H. S., Ko, J., Culler, D. E., Paek, J. (2017). Challenging the IPv6 routing protocol for low-power and lossy networks (RPL): A survey. IEEE Communications Surveys Tutorials, 19(4), 2502-2525.

[Kumar and Kumar 2019] Kumar, N. S., Kumar, K. R. (2019). A collision aware priority level medium access control protocol for underwater acoustic sensor networks. Journal of Information and Communication Technology, 19(1), 131-156.

[Lee et al.2018] Lee, H., Lee, K. J., Kim, H., Lee, I. (2018). Wireless information and power exchange for energy-constrained device-to-device communications. IEEE Internet of Things Journal, 5(4), 3175-3185.

[Liu et al.2019] Liu, X., Zhao, S., Liu, A., Xiong, N., Vasilakos, A. V. (2019). Knowledge-aware proactive nodes selection approach for energy management in Internet of Things. Future generation computer systems, 92, 1142-1156.

[Lin et al.2018] Lin, C. Y., Liao, K. H., Chang, C. H. (2018). An Experimental System for MQTT/CoAP-based IoT Applications in IPv6 over Bluetooth Low Energy. J. UCS, 24(9), 1170-1191.

[Murali and Jamalipour 2018] Murali, S., Jamalipour, A. (2018). Mobility-aware energy-efficient parent selection algorithm for low power and lossy networks. IEEE Internet of Things Journal, 6(2), 2593-2601.

[Natesan and Krishnan 2020] Natesan, S., Krishnan, R. (2020). FLCEER: Fuzzy Logic Cluster-Based Energy Efficient Routing Protocol for Underwater Acoustic Sensor Network. International Journal of Information Technology and Web Engineering (IJITWE), 15(3), 76-101.

[Nguyen et al.2018] Nguyen, T. D., Khan, J. Y., Ngo, D. T. (2018). A distributed energy-harvesting-aware routing algorithm for heterogeneous IoT networks. IEEE Transactions on Green Communications and Networking, 2(4), 1115-1127.

[Purkovic et al.2018] Purkovic, D., Hönsch, M., Meyer, T. R. M. K. (2018). An energy efficient communication protocol for low power, energy harvesting sensor modules. IEEE Sensors Journal, 19(2), 701-714.

[Raoof et al.2018] Raoof, A., Matrawy, A., Lung, C. H. (2018). Routing attacks and mitigation methods for RPL-based Internet of Things. IEEE Communications Surveys Tutorials, 21(2), 1582-1606.

[Sankar and Srinivasan 2017] Sankar, S., Srinivasan, P. (2017). Composite metric based energy efficient routing protocol for internet of things. International Journal of Intelligent Engineering and Systems, 10(5), 278-286.

[Sankar and Srinivasan 2018] Sankar, S., Srinivasan, P. (2018). Energy and load aware routing protocol for internet of things. International Journal of Advances in Applied Sciences (IJAAS), 7(3), 255-264.

[Sanshi and Jaidhar 2019] Sanshi, S., Jaidhar, C. D. (2019). Fuzzy optimised routing metric with mobility support for RPL. IET Communications, 13(9), 1253-1261.

[Sennan et al.2019] Sennan, S., Balasubramaniyam, S., Luhach, A. K., Ramasubbareddy, S., Chilamkurti, N., Nam, Y. (2019). Energy and Delay Aware Data Aggregation in Routing Protocol for Internet of Things. Sensors, 19(24), 5486.

[Shen et al.2019] Shen, Z., Jiang, H., Dong, Q., Wang, B. (2019). Energy-Efficient Neighbor Discovery for the Internet of Things. IEEE Internet of Things Journal, 7(1), 684-698.

[Singh and Chen 2019] Singh, P., Chen, Y. C. (2019). RPL Enhancement for a Parent Selection Mechanism and an Efficient Objective Function. IEEE Sensors Journal, 19(21), 10054-10066.

[Tian et al.2015] Tian, X., Zhu, Y. H., Chi, K., Liu, J., Zhang, D. (2015). Reliable and energy-efficient data forwarding in industrial wireless sensor networks. IEEE Systems Journal, 11(3), 1424-1434.

[Xu et al.2019] Xu, C., Xiong, Z., Zhao, G., Yu, S. (2019). An energy-efficient region source routing protocol for lifetime maximization in WSN. IEEE Access, 7, 135277-135289.

[Zhao et al.2016] Zhao, M., Ho, I. W. H., Chong, P. H. J. (2016). An energy-efficient region-based RPL routing protocol for low-power and lossy networks. IEEE Internet of Things Journal, 3(6), 1319-1333.