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"IMPROVED LOAD BALANCING PROTOCOL FOR WSN "

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Abstract: Load balancing is a valuable approach to improve the energy efficiency of Wireless Sensor Networks (WSNs) that utilize the Routing Protocol for Low Power and Lossy Network (RPL). However, traditional RPL faces challenges in handling mobility, leading to disruptions in paths, increased energy consumption, and higher network delays. The integration of mobile nodes in Internet of Things (IoT) applications opens up opportunities for innovative services. This paper emphasizes the significance of load balancing and energy efficiency in RPL-based IoT networks and offers valuable insights into the ongoing research trends in this domain. Through load balancing and optimized energy consumption, RPL can enhance performance and prolong the operational life of IoT devices within networked environments.

Keywords: COOJA simulator, IoT, BE-RPL, load balancing, RPL.

1. Introduction

Due to recent developments in embedded devices and data connection protocols, the Internet of Things has become a significant technology [1].Wireless Sensor Networks (WSN) are vulnerable to security vulnerabilities, similar to mobile ad hoc networks. [2,3]. The 6LowPAN innovation is used to connect WSN devices to the Internet. By doing so, even small devices may join an IP network. When it comes to memory, energy, and computational resources, WSN devices are asset-obsessed. [4] . In that they are vulnerable to attack, Mobile ad hoc networks (MANETs) and wireless sensor networks (WSNs) are comparable due to important developments in embedded systems and data links Due to recent developments in embedded technology and data connection protocols, the Internet of Things has become a significant technology [1]. The interconnection of devices that are asset-obsessed leads to high loss rates, slow data rates, and inconsistent behaviour [5] [28] Low-power and Lossy networks find applications in various fields, such as industrial automation, smart buildings, smart education, medical aid, health monitoring, and senior care, among others [6–9] clinical monitoring sensors with real-time data transmission. Patients are mobile nodes that move about freely and interact with the design of fixed nodes, creating traffic. In an IP-based system, using traditional LLN routing methods is unacceptable [10] [29]. Interoperability issues on the Internet have emerged despite the existence of numerous unique protocols. To solve this problem, The Routing Protocol for Low-Power and Lossy Networks was created by the IETF, or Internet Engineering Task Force. RPL was created to meet the requirements of the 6LowPAN adaptation layer, making it suitable for LLN routing. This study focuses on "micro-mobility," which is the movement of nodes inside a network without changing their addresses. The biggest issue with LLN is the disappearance of nodes when they lose power or relocate [11] 12] [30]. RPL offers both local and global correction strategies to address these problems [13]

[31] To overcome these issues We provide an RPL protocol that is clear, balanced in load, and energy-efficient. It keeps track of node movement and proactively starts handover processes.

2. Related work

The RPL routing tree is created using the DODAG (Destination Oriented Directed Acyclic Graph) [14] .The RPL supports all types of communications; including point-to-multipoint, point-to-point, and point-to-point [15] [35].Goals are the foundation of a DODAG [16]. The RPL uses four unique IDs to keep track of topology. Each node in the network is given a rating. The ranking is based on the measurements, the target function, and the node's separation from the DODAG root. When moving higher, rank strictly diminishes, whereas moving below, rank strictly increases. The DODAG Information Object (DIO), DODAG Information Solicitation (DIS), Destination Advertisement Object (DAO), and DAO Acknowledgement (DAO-ACK) are the four new ICMPv6 control messages introduced by RPL. The initial DIO transmission comes from the root node. Once they locate their preferred parent (PP) node, Leaf nodes are nodes that join after receiving this DIO [17] [34] after locating PP, each node anticipates its position. After then, the DIO is recreated and transmitted. Node in the topology can join the DODAG until all of them do. this cycle continues. To request DIO communications from neighbours, send them a DIS message. The ability to allow downward traffic is provided by a DAO control message. The receiving DAO is acknowledged with a DAO-ACK. Node mobility in DODAG results in inconsistency. RPL does not provide mobility identification. It doesn't make a distinction between stationary and moving nodes. RPL detects topology changes using the trickling timer mechanism or the IPv6 Neighbour Discovery method. RPL recognises changes in network topology and applies a local or global repair mechanism to fix the disparity.

3. Literature Review

In this part, we briefly discuss some research on RPL when nodes are mobile. The authors of [18] discuss the potential for RPL mobility within a VANET. They turn off the DIO trickle timer to account for frequent topology changes. Second, they suggested that connection quality be taken into account when updating the routing graph. They also added parent IDs in DIO messages to avoid loop issues.

In place of RPL, the writers proposed VANET for GI-RPL [19] [32] substitute. Localization procedures were used to deal with topological changes that occurred often. They offered a programmable DIO period that boosts efficiency by boosting packet delivery efficiency and lowering packet latency. The GI-RPL algorithm did not account for energy restrictions.

The Mobility Enhanced RPL (MERPL) was proposed by the authors of [20]. The desired parent was a static node, which increased the route's stability, requesting DIO messages, which were utilised to rejoin after the gap, by sending numerous DIS messages, prevented mobile node disconnections. MERPL does not consider handover latency, signalling costs, or energy consumption.

As they go to new areas, mobile nodes are entrusted with starting the handoff process using the aforementioned methods. In general, mobile nodes are under-equipped. Since mobile nodes have limited capabilities, a method for managing mobility must be provided by other nodes, called parent nodes. Parent nodes are intended to have more resources, including computing power, bandwidth, and battery life, than mobile nodes.

The developers of EMA-RPL [22,33] suggested using a method for detecting mobility based on received signal strength indicators (RSSI). Information is gathered by mobile nodes from nearby static nodes. By sending a sequence of control messages to a neighbouring static node, a mobile node can determine the RSSI. A new ideal set of parents is selected with the help of the median RSSI. While parent nodes can handle mobility for their children, the more children there are, the more of a toll it may have on the parent node's performance in terms of data transmission delay, residual energy, and an increase in the number of control messages.

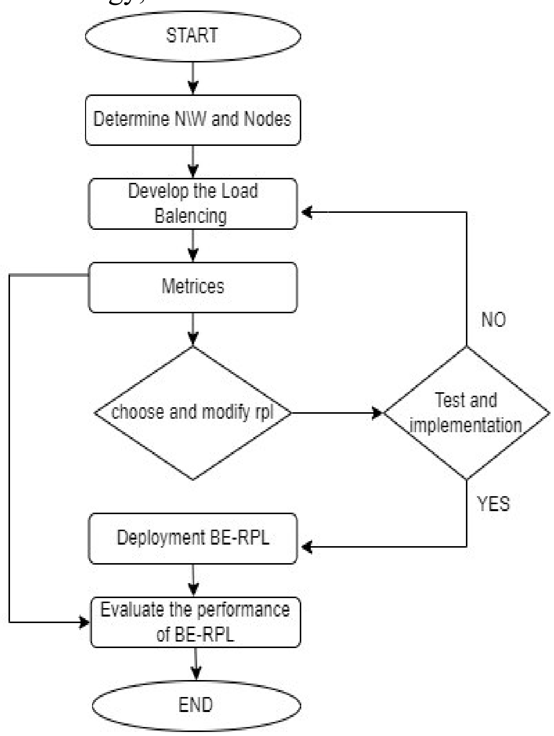

Fig 1: Flowchart

4. Terminologies, Control Packets, and Timers for BE-RPL

This section contains definitions for the terms and numbers used in the recommended solution. The adjustments to the control packets are included. The three types of nodes that make up the recommended treatment for DODAG are the DODAG root node, the Stationary Node (SN), and the Mobile Node (MN).

SNs are thought to be quite resourceful. MNs with insufficient resources are assigned SNs as their parents. The total number of MNs that are attached to the stationary node as leaf nodes is known as the AMN Count (Associated Mobile Node Count).

4.1 BE-RPL Protocol

The RPL (Routing Protocol for Low-power and Lossy Networks) protocol is commonly used in LLNs (Low-power and Lossy Networks), such as those used by Internet of Things (IoT) devices. This protocol has a variant known as the Best Effort RPL (BE-RPL) protocol.

In RPL's default joining procedure, MN (Mobile Node) initiates a connection with the DODAG (Destination-Oriented Directed Acyclic Graph) instance and selects its preferred parent node. The protocol incorporates three essential phases: mobility monitoring, election, and attachment. These phases work together to detect any movement of the node and facilitate a smooth handover process to maintain connectivity during mobility events

During the initial stage, the parent node uses the RSSI (Received Signal Strength Indicator) value to monitor the movement of MN (Mobile Node). When MN moves away from the parent node beyond a certain threshold, it triggers the election process to select a new preferred parent (PP). Subsequently, MN disconnects from its previous PP and joins the newly elected PP as a leaf node during the attachment phase. This process ensures seamless handover and continuous connectivity for the mobile node

4.2 Phase of Mobility Monitoring

During this phase, nodes that are on the move periodically broadcast their location information to their neighbours using RPL's DIO (DODAG Information Object) messages. The DIO messages contain information about the node's rank, parent, and other network parameters the mobility monitoring phase plays a crucial role in ensuring that RPL is able to maintain reliable and efficient routing in dynamic and mobile networks, such as those found in IoT applications

4.3 Election Phase

Each node in the network transmits a DIO (DODAG Information Object) message including its rank and other pertinent network parameters during the election phase. The root of the DODAG tree is the node with the lowest rank, and all other nodes in the network are its children.

5. Performance Assessment

Several measures, including network throughput, packet delivery ratio, energy consumption, and network lifespan, may be used to evaluate the performance of BE-RPL (Best Effort RPL) and contrast it with conventional RPL and EMA-RPL (Exponential Moving Average RPL).

In order to evaluate the performance of the proposed BE-RPL and compare it to that of the conventional RPL and the EMA-RPL, we simulated the BE-RPL. The COOJA simulator is used to examine the BE-RPL on the Contiki platform. Contrary to earlier simulators, COOJA enables concurrent simulation at several levels by combining high-level behaviour modelling with low-level hardware simulation in a single simulation. The existence of a mobility plugin in COOJA and a widely used RPL implementation are the main justifications for choosing Contiki. Depending on the exact network topology and circumstances, the performance of BE-RPL, standard RPL, and EMA-RPL may differ. Therefore, it's crucial to assess each protocol's performance in the particular application environment and select the best option depending on the performance needs and limitations.

5.1 Simulation Setup

The RPL-LITE and RPL-CLASSIC versions are supported by Contiki. RPL Classic is utilised for analysis. The simulation method of choice is the Unit Disc Graph Model (UDGM) with distance loss scheme. We used Zolertia Z1 motes in our simulation. The simulation method of choice is the Unit Disc Graph Model (UDGM) with distance loss scheme. We used Zolertia Z1 motes in our simulation.

The element for energy is activated to track each mote's energy consumption. Now we will incorporate and apply the mobility extension of the random walk model.

Both In order to compare BE-RPL with EMA-RPL, Contiki RPL_CLASSIC is used.The number of mobile nodes determines the simulation of various scenarios. The SNs are organised in a grid that is linear. In every situation, we consider energy consumption, ratio of delivered packets and control of packet overhead.

Table 1: Simulation Parameters

Parameters	Details
Area for simulation	200 m × 200 m
Simulation period	3600s
Stationary nodes	15
Mobility nodes	1, 2
Traffic pattern	Constant Bit Rate
Ratio of transceivers	Reception (Rx) = 100%, Transmission (Tx) = 100%
The mobility model	RWM
Timer	Timer for DIS-Delay:60 ms Timer for DIS-Burst: 20 ms

5.2 Control Overhead

The efficacy of BE-RPL was evaluated in comparison to that of EMA-RPL and baseline RPL. The proportion of packets transported, the end-to-end delay, the network's lifetime, and its energy usage are just a few examples of the metrics that can be employed. The percentage of packets that make it from the sending node to the receiving node is known as the "packet delivery ratio" (PDR). When the PDR is higher, the performance is better. End-to-end delay is the total amount of time it takes for a packet to transit from its originating node to its final destination. The latency of a network is reduced when the end-to-end delay is smaller.

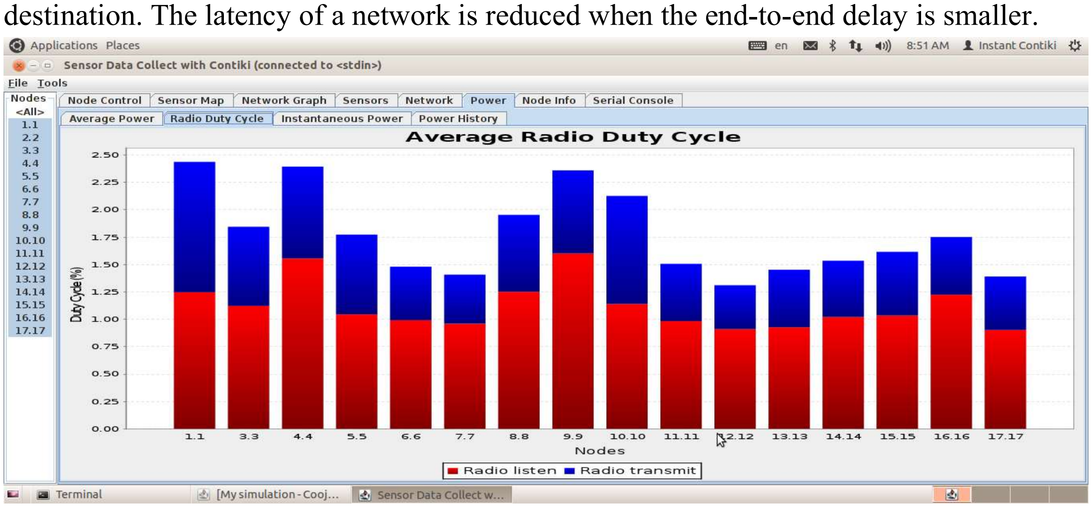

Fig 2: Average radio duty cycle

5.3 Utilisation of Energy

Low-power electronics are impacted by several problems, with energy consumption ranking as their biggest problem. The CPU's energy usage in active, low power, and deep low power modes is evaluated by the energy monitoring module. Additionally, it monitors the radio transceiver's energy consumption in both transmission and reception modes. The Zolertia Z1 mote makes use of the CC2420 radio transceiver. This mote consumes 19.7 mA for reception and 17.4 mA for transmission at 3 V [26]. Indirectly, the Energest module offers information about energy consumption [27]. It displays the amount of time the transceiver spends in each state. The sign for it is RTIMER_SECOND. COOJA simulation with five mobile nodes 794 CSSE, 2023, vol. 45, no. 1 per second for actual time are 32770 for the CC2420 transceiver. The energy expended at a specific state is determined using the time, current, and voltage there. for instance, provides the quantity of energy used during the transmission state.

5.4 Energy Consumption of Individual Nodes

The energy consumption of a node in the RPL method can be calculated using the quantity of energy used models of the components of the node, such as the radio, sensors, and CPU. For example, the energy consumption of the radio can be calculated using the formula:

$$E_{radio} = P_{tx} * t_{tx} + P_{rx} * t_{rx} + P_{idle} * t\_idle$$

Where E_{radio} is the energy consumption of the radio, P_{tx} is the power consumption during transmission, P_{rx} is the power consumption during reception, P_{idle} is the power consumption during idle mode, t_{tx} is the transmission time, t_{rx} is the reception time, and t_{idle} is the idle time

The energy consumption of the routing protocol can be calculated using the formula:

$$E_{RPL} = n * E_{msg}$$

Where E_{RPL} is the energy consumption of the RPL protocol, n is the number of control messages sent and received, and E_{msg} is the energy consumption of a single control message. Energy Consumption of the Network: The energy consumption of the entire network can be measured by analyzing the energy consumption of all the nodes and the routing protocol. The energy consumption of the network can be calculated using the formula:

$$E_{network} = E_{nodes} + E_{RPL}$$

$E_{network}$ is the energy consumption of the network, E_{nodes} is the total energy consumption of all the nodes, and E_{RPL} is the energy consumption of the RPL

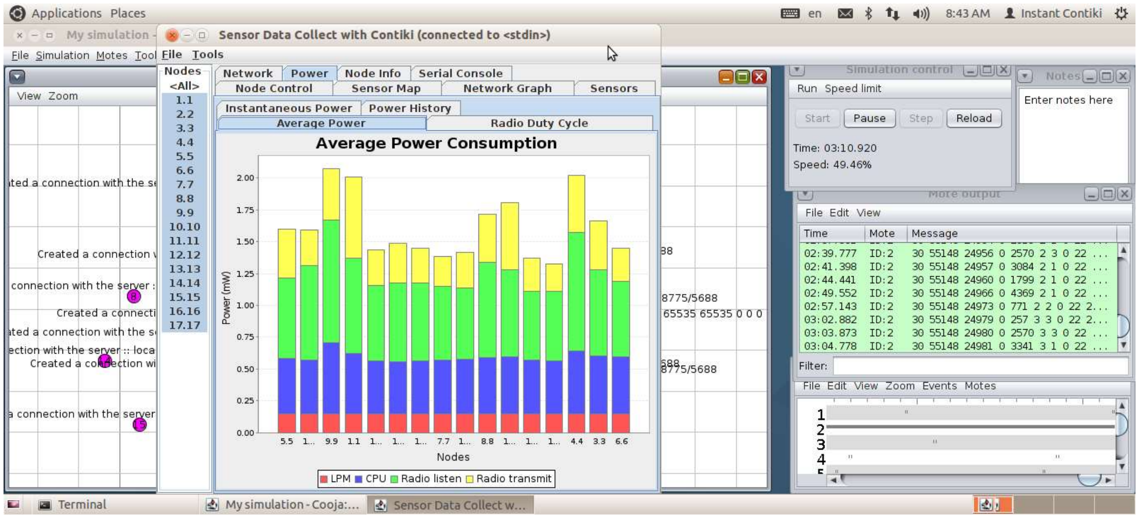

Fig 3: average power consumption

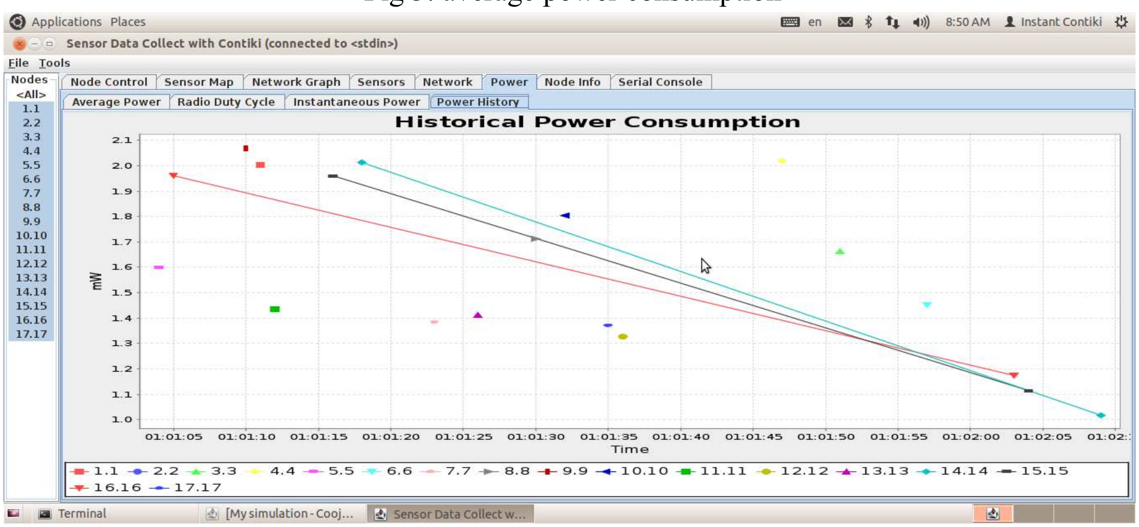

Fig 4: power consumption

5.5 Deliverability of packets

The packet delivery ratio (PDR) of conventional RPL, EMA-RPL, and BE-RPL is calculated by comparing the number of packets that were successfully delivered to the destination node to the total number of packets sent. Packet-level simulations or practical tests on a testbed can be used for this.

We compute the packet delivery ratio (PDR) for the traditional RPL, EMA-RPL, and BE-RPL in order to improve network reliability. For static nodes, PDR is consistently 100%. Mobile nodes have a lower PDR. According to fig 4, one mobile node can carry 59%, 80.16%, and 84.24% of the packets for RPL, EMA-RPL, and BE-RPL, respectively.

Reduced connection failure frequency thanks to BE-RPL increases route stability. Deliveries of packets increase as a result. demonstrates the average end-to-end packet delivery ratio for each of the five scenarios. In a scenario involving five mobile nodes, 90.21% end-to-end PDR is achievable with BE-RPL. For the same scenario, Both the EMA-RPL and the conventional RPL are 88.14% and 84.61%, respectively. In terms of PDR, BE-RPL outperforms EMA-RPL since MN quickly develops a relationship with the new preferred parent. The BE-RPL works well since it addresses SN load balancing. A network called BE-RPL seems more reliable when compared to the EMA-RPL and traditional RPL networks.

5.6 Frame Acknowledgement Ratio

When the acknowledgement request field is set to 1, the proportion of received acknowledgements to transmitted frames is 1.When the acknowledgement request field of a data or MAC command frame in wireless communication is set to 1, it indicates to the recipient that they must confirm that they received the frame. A good frame reception requires the recipient to respond with an acknowledging frame. The acknowledgment frame need to have the same data sequence number (DSN) as the data or MAC command frame that it is acknowledging.The receiver must deliver the acknowledgement frame as soon as possible after receiving the last symbol of the data or MAC command frame in order to guarantee that it is received in a timely manner. This period is called the Turn a round Time plus a Unit Back off Period symbols, where Turn a round Time is the time required for the receiver to switch from receiving to transmitting mode, and a Unit Back off Period is a configurable time period that determines how long the receiver must wait before transmitting the acknowledgement. By dividing the total number of acknowledgements received by the total number of frames transmitted while setting the acknowledgement request field to 1, the frame acknowledgement ratio (FAR) is determined. A higher FAR indicates better reliability of the wireless link and a lower likelihood of packet loss. FAR is an important metric for evaluating the performance and reliability of wireless communication networks, particularly in real-time applications where data transmission is critical. By monitoring FAR, we can assess the quality of the wireless link and take corrective measures to improve the reliability of the communication

Fig 5: Sensor data collect view (Light 1)

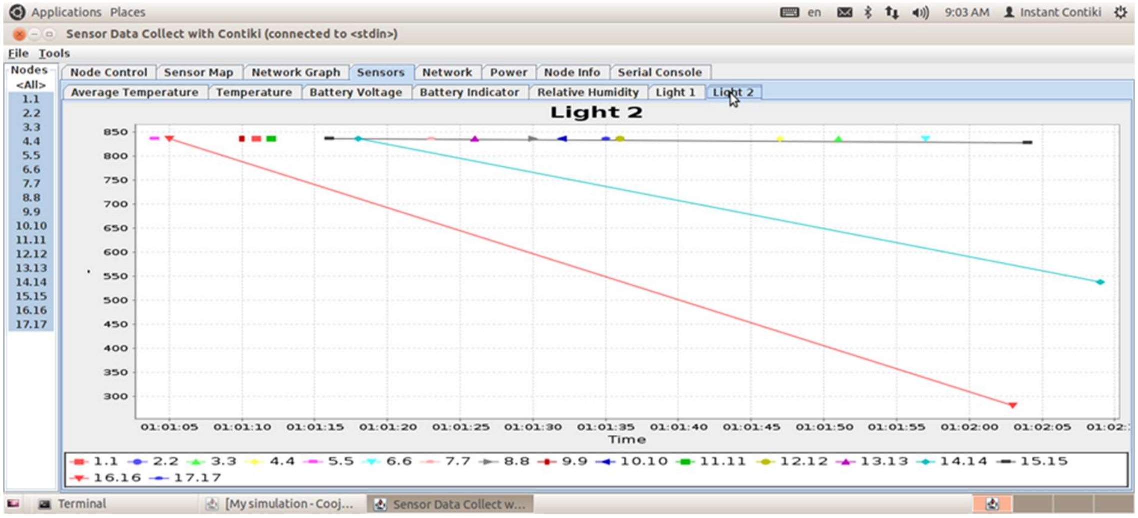

Fig 6: Sensor data collect view (Light 2)

6. Conclusion

Load balancing is an important technique that can be used to enhance the performance and energy efficiency of RPL-based networks. By distributing traffic load evenly across the network nodes, load balancing can help to prevent congestion and reduce the likelihood of node failure, which can in turn improve the reliability of the network. Additionally, load balancing can help to reduce energy consumption by ensuring that no node is overwhelmed with too much traffic, which can lead to excessive energy consumption and premature battery depletion. Overall, load balancing is a valuable technique for optimizing the performance and energy efficiency of RPL-based networks, and it is important for network designers to consider load balancing strategies when designing and deploying these networks.

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