RPL Based Routing Protocols for Load Balancing in IoT Network

Sangeeta Rani¹, Ajay Kumar¹, Arko Bagchi¹, Snehlata Yadav², Sachin Kumar³
¹Shree Guru Gobind Singh Tricentenary University, Haryana, India
²KR Mangalam University, Haryana, India
³Sat Kabir Institute of Technology and Management, Jhajjar
E-mail: sangeeta.sept@gmail.com, ajay.kumar30886@gmail.com

Abstract. RPL is a direct routing convention for remote organizations with low force utilization and large defenseless to parcel misfortune. It is a proactive convention dependent on distance vectors and works on IEEE 802.15.4. RPL can uphold a wide assortment of connection layers, including IoT, which is a technology that taking hold of research and industries with a fast tramp. It is a collection of actuators and sensors that collect data which can be processed to produce actual information. Important parameters allied to human body and physical environment data such that humidity, temperature, pressure, pollution etc. have immense significance for computerization, failure recognition, well timed, and appropriate cure. In this manner, IoT network offered ascend to keen urban communities, home mechanization, savvy wellbeing, present day travel strategic and some more. There is a distance vector normalization Routing Protocol for Low force and Lossy organization (RPL) for IoT sending, which relies upon different course improvement Objective functions (OF). These capacities rely upon different networks in the vein of energy like Received Sign Strength Indicator (RSSI) and Expected Transmission tally (ETX) for course streamlining. Course enhancement is influenced by issue of burden adjusting. In this paper, an inclusive survey of existing load balancing schemes, matrices, Objective Functions and different RPL based Routing protocols with reference to load imbalance is represented and highlighted when load balancing merged with the RPL, how it had a great impact. Keywords: RPL, IoT, Objective Functions, RSSI, ETX.

1. Introduction
In modern existence, across the world billions of sensors have been deployed, where the most complicated network is IoT [1]. It includes many significant areas like industry, health care, agriculture and transportation. These fields comprise with features of large-scale network, IP based network, and automation which can provide latest category of Quality of Service (QoS) for flexible and smart network [1]. Moreover, the consolidation of immense measure of IoT included hubs transform into a region of exploration, web designing Task Force (IETF) backing to start RPL approaches with respect to these issues, diverse examination regions can be indicated in organized to lead the vision of IoT [2]. RPL is a distance vector steering convention travel for IPV6 gadgets. It works with 6LoWPAN adaption layer on IEEE802.15.4 standard. RPL works with ZigBee which is a correspondence convention and can be straightforwardly sent to the utilizations of IoT [3]. RPL structures a treelike geography Destination Oriented Acyclic Graph (DODAG) having leaves at the limits. All DODAG hubs are compartment with DODAG root, which is a solitary sink hub. DODAG covers entire organization, are called DAG [4]. IETF normalized two target capacities Objective Function Zero (OF0) and Minimum Rank Hysterlsis Objective Function (MRHOF), which choose the course by clarifying Optimization goals, steering
frameworks and related capacities in DODAG. Target Function OF0 consider bounce tally to find the way to the root and MRHOF utilizes ETX for upgrading way [5].

![RPL Structure](image)

**Figure 1. RPL Structure**

Authors have introduced several performance evaluation studies of RPL which can estimate end to end delay of packets, energy usage and packet loss. But authors have not investigated how packet delivery ratio can be affected with average power transmission. To lessen the parcel misfortune research was completed in 6LoWPAN Network [6]. Zhang et. al. in [7] conveyed towards ContikiRPL assessment in Cooja however it was not explicit to a specific application. Gnaleb et al. in [8] extended an improved RPL to crush the limitation on the parent hubs stockpiling abilities. Muneer et al. in [10] examine comprehensively two huge remote organization stages have been encased regarding bundle overhead, parcel conveyance proportion and parcel dynamicity when hubs may join or detach the organization. The creators show through different experimentation how the soundness of the steering arrangement influenced by hub disappointment. Ha Kwon et al. in [11-12] stretched out the RPL to accomplish unwavering quality, energy effectiveness and low defer information move. The creators colored that heap adjusting, multipath directing and various sinks had an immense effect when it is joined with the RPL.

### 2. RPL with load balancing

In RPL, Load adjusting makes the exchange as predictable as attainable, while decreasing force usage of hubs [13]. Various endeavors can be conceivable to achieve balance in exchange, In request to lessen parcel drop and blockage. To give a reasonable tree in RPL numerous Objective capacities have been proposed. RPL based Objective Functions These are the procedures used by nodes to select path in RPL. They work with routing matrices like Hop Count, ETX, Parent Count and buffer occupancy. The default Objective Functions such as OF0 and MRHOF calculate the rank based on the routing matrices like packet delivery ratio.

Examination [29] foreseen a heap adjusting enhancement utilizing Q-Learning (LBO-QL). It can adjust the heap through RPL creation and applies a Q-Learning method to stack adjusting streamlining for calamity situations. In Q-Learning approach, organization’s traffic flood can be kept away from, the hub
Figure 2. Objective Functions Features

need to know just the halfway parent hub. By utilizing Contiki and Cooja test system LBO-QL is executed as a RPL directing convention Objective Function. Execution of organization can be intentional with parcel conveyance proportion, energy Consumption and Convergence time control. Target work LBO-QL blesses with network help, improve network execution and give capable bundle conveyance proportion. Issue: It doesn’t cover all the part of RPL configuration steering measure and not think about the connection Quality.

Figure 3. DODAG in RPL for Smart City
| Sr. No. | Authors                  | Objective Function | Function                                                                 | Routing Metric | Performance Metric                        | Application Scenario                  | Advantage                                                                 |
|--------|--------------------------|--------------------|--------------------------------------------------------------------------|----------------|-------------------------------------------|----------------------------------------|--------------------------------------------------------------------------|
| 1.     | B.Y. Firas et. al. [18]  | Objective Function 0 | Pick a way which has least number of jumps                               | Hop count      | Energy consumption and Packet Delivery Ratio (PDR) | Home Automation, Streetlamp           | Most limited way first will be picked                                    |
| 2.     | B.Y. Firas et. al. [18]  | Objective Function 1 | Pick a way which has least number of retransmission when sending parcel  | Hop count      | Energy consumption and Packet Delivery Ratio (PDR) | Home Automation                        | lessen bundle retransmission                                              |
| 3.     | Zibuyisile et. al. [21],[29] | Least Rank with Hysteresis Objective Function (MRHOF) | To discover the ways with the littlest way cost while forestalling unreasonable stir in the organization | Load balancing and Burden adjusting metric-based steering for RPL (lbRPL), Expected Transmission tally (ETX) and Hop check | Packet conveyance proportion, Network lifetime through Node Participation, Control Traffic Overhead | Smart home automation, data delivery and network reliability | Appropriate for use in sensor network that require information conveyance in the dependable organization |
| 4.     | Zibuyisile et. al. [21],[33] | Traffic Aware Objective Function (TA-OF) | To decide the best way dependent on distance. | Transmission Rate (PTR), Expected Transmission count (ETX) | Energy consumption - Packet Deliver Ratio | Smart cities and wearable devices | Better in adjusting the organization geography, accomplishes the dependability better than default RPL target capacities. It likewise diminishes the bundle over-burden in the hubs. |
| Sr. No. | Authors                  | Objective Function                        | Function                                                                 | Routing Metric | Performance Metric                  | Application Scenario                              | Advantage                                                                 |
|--------|--------------------------|-------------------------------------------|--------------------------------------------------------------------------|----------------|-------------------------------------|-------------------------------------------------|--------------------------------------------------------------------------|
| 5.     | Eriksson et al. [26]     | Context-Aware Objective Function (CA-OF) | Selecting a goal to pursue, among many that are deemed.                  | Buffer Occupancy (BO), Expected Transmission count (ETX) | Packet delivery ratio - Energy consumption - Throughput | Home automation, industrial control, urban environment and building automation | Better network throughput, better packet delivery ratio, and less energy consumption, network lifetime extension, and high efficiency |
| 6.     | B.K. Tarcisco et al. [30] | A LoAd Balancing MOdel (AL-ABAMO)          | Used to help hubs in picking the best parent to be utilized.             | Expected Transmission Count (ETX) | Network delivery ratio - Energy Consumption - Network lifetime | Multi-hop data collection as environmental monitoring | Compatible with RPL and provides traffic-aware balanced routing.          |
| 7.     | B. Dubai et al. [31]     | Balanced Ad-hoc Network Formation, BNOF(Stateless) | pick a way which equilibrium directing sections in the hubs             | -                           | -                                   | Farming, Smart meter                             | Balance network load when all the hubs produce roughly comparative measure of traffic |
| 8.     | B. Dubai et al. [31]     | Balanced Ad-hoc Network Formation, BNOF(Stateful) | Pick a way which equilibrium network traffic among hubs                | ETX-based routing metric approach | -                                   | Smart City, Smart meter, Building Automation     | Balance network load when the hubs produce lopsided measure of traffic    |
| 9.     | O. Gad-dour, et al. [34] | QoS-Aware Fuzzy Logic Objective Function (OF-FL) | To develop a way that upgrade or oblige a steering metric on the ways. | ETX, bounce check, start to finish deferral and battery level | Normal jump check, End-to-end delay, Average excess energy | Path optimization                              | Performs in a way that is better than standard RPL as far as strength, energy utilization, and bundle conveyance |
3. Load Balancing Problem with RPL Protocol

Congestion avoidance and load adjusting are not considered in the RPL steering convention configuration measure. In the parent determination measure the traffic fleeting throughout parent nodes were not considered. This causes unbalance structure. There are different studies on RPL load balancing.

3.1. Imbalanced Tree Algorithm

It is a ravenous calculation to take care of issues of Load adjusting. For ID of hubs that are inclined to the clog load balance factor has been determined at each degree of directing. Point of this technique is to limit the heap irregularity factor and equilibrium the directing tree. From three nominated parents one parent has been selected and the root node executes the algorithm. During network lifeline, this is to be done occasionally for keeping the tree as much as balanced. This algorithm keeps the load balanced among nodes and appreciable increase the network lifeline and average packet delivery ratio.

3.2. TREEB Algorithm

In this algorithm, nodes want to join DODAG must know about the total number of nodes in each subtree. It will try to remain tree size same but had no effect on load balancing. [17]. This algorithm is completely ineffective with only one root and increase overhead. While planning RPL directing convention load adjusting is fundamental factors that should be thought of. ETX is the most widely recognized directing networks which have been fixed with RPL steering convention. ETX can give association between various hubs. It depends on three ideas: The Parent Selection, the Path cost count and the rank calculation.RPL unmistakably depends on Objective Functions. [18].This adaptability in the OFs keep RPL talented for any application situations here and there the OF’s should be changed and afterward another OF can be executed for burst traffic [19].

4. RPL Based Routing Protocols

RPL does not believe Load Balancing for steering convention for IoT. To tackle with load balancing in RPL, researchers anticipated different proposals by which network lifetime and packet diversity can be increased and load rescheduling can be decreased [21].

The current RPL-base burden changing game plans can be arranged as:

**Figure 4. LLN Routing Protocols**
| Sr. No. | Authors | Routing Protocol | Operating System | Type | Topology | Algorithm | Scalability | Memory Usage | Energy Usage | Supported Traffic | IPv6 Support | Performance Metrics |
|--------|---------|------------------|------------------|------|----------|-----------|-------------|--------------|--------------|----------------|--------------|-------------------|
| 1.     | Packet Delivery ratio et. al [22] | LB-RPL | NS-2 | Proactive | Flat | Distance Vector | High | Less | Less | P2P | Yes | Packet Delivery Ratio, End-to-End Delay |
| 2.     | Taghizadeh et. al [23] (CL-RPL) | Contiki | Proactive | Hierarchical / Flat | Distance Vector | High | High | High | P2P, M2P | Yes | Queue Loss, Packet delivery Ratio, Energy consumption |
| 3.     | H. Kim [24] Que-Utilization (QU-RPL) | Tiny OS | Proactive | Flat | Distance Vector | Less | High | High | P2P, MP2P | Yes | Packet Delivery ratio, |
| 4.     | Tang [25] Clustered additive (CA-RPL) | Contiki-OS | Proactive | Hierarchical / Flat | Distance vector | High | Average | Less | P2P | Yes | Packet Delivery ratio, Energy conservation, Average Delay |
| 5.     | Sennan et. al [28] Energy and Load Aware EL-RPL | Contiki-OS | Reactive | Flat | Distance Vector | High | Average | Average | P2P | Yes | Packet Delivery ratio, Throughput |
| 6.     | Dawson et. at [35] Beacon Vector routing (BVR) | Contiki | Geographical | Hierarchical | Greedy Forwarding | High | High | High | P2P | Yes | Energy Consumption, Packet delivery ratio. |
| 7.     | Ming Dawson et. at [35][36] | Hydro | Contiki OS | Proactive | Hierarchical / Flat | Source Routing | High | Average | High | MP2P, P2P, P2MP | Yes | Packet Delivery ratio |

Table 2. RPL Based Routing Protocols
| Sr. No. | Authors         | Routing Protocol | Operating System | Type | Topology | Algorithm | Scalability | Memory Usage | Energy Usage | Supported Traffic | IPv6 Support | Performance Metrics                                      |
|--------|-----------------|-------------------|------------------|------|----------|-----------|-------------|--------------|--------------|-----------------|--------------|----------------------------------------------------------|
| 8.     | Gomez et. al. [37] | NST-AODV         | Tiny OS          | Reactive | Flat   | Distance Vector | High        | Less         | Less         | MP2P, P2P     | Yes          | Packet Delivery Ratio, high throughput                   |
| 9.     | Pham et. al. [38]  | Tiny AODV        | Tiny OS          | Reactive | Flat   | Distance Vector | High        | Less         | Less         | MP2P, P2P     | Yes          | Packet Delivery Ratio, high throughput, average delay   |
| 10.    | Vucinic et. al. [39] | LOADng Contiki OS | Reactive | Flat | Distance Vector | High        | Less         | P2P          | No            | Energy consumption, packet delivery ratio, Better acceptable path |
| 11.    | Long et. al. [40]  | CTP              | Tiny OS          | Proactive | Flat | Source Routing | High        | Less         | MP2P, P2MP   | No            | Energy consumption, packet delivery ratio               |
| 12.    | Goyal et. al. [41] | P2P RPL          | Contiki          | Proactive | Flat | Distance Vector/Source Routing | High        | High         | High         | MP2P          | No           | Path Quality metrics, Packet Delivery ratio             |
| 13.    | Xie HF et. al. [42] | ZigBee Clustering tree | Contiki     | Proactive | Flat | Link State | High        | High         | High         | MP2P          | No           | Energy efficiency, Minimum delay                        |
The RPL-based directing shows give different approaches to manage understanding burden changing and blockage in network in Low Power and Lossy Network. It should be excused on how it impacts the energy use of focus focuses and time delays while the kid place point looking for the parent community with less bundles.

5. Discussion and Future Direction
The researchers in the past examinations address the Load Balancing in RPL while others projected directing convention based on RPL and target works that manage load adjusting issues. This paper gives the cutting edge of RPL execution in IoT appropriated networks and talk about the proposed arrangements to move towards the load balancing in RPL. The paper audits all proposed arrangements by the researchers to ease the issues of Load Balancing in IoT. The essential responsibility of this paper is to give the analysts with the work that analyzes, inspects and overview the examination approaches made to address the Load changing issue in RPL. This survey gives extra understanding into different load adjusting arrangements dependent on RPL convention.

6. Conclusion
Problem of Load Balancing can be comprehended. Lots of plans anticipated to deal with RPL load evolving issue. Incrdbly these plans have several prerequisites. RPL is unacceptable to coordinate transfer superior in enormous augmentation affiliation, proposed store changing approaches are reasonable for various affiliation conditions. This paper mentioned the plans as appeared by its highlights. Examined the RPL-based organizing show, its presentation assessments, and the restrictions. The RPL-based organizing shows continue as shown by the showcase assessments utilized on it. A tremendous section of the investigated guiding shows are restricted to bundle transport degree additionally, parent confirmation. Just one out of each odd one of them wires energy use, to achieve best in IoT, RPL should be power cautious. Organizing assessments which can manage the presentation in RPL thinks about affiliation superiority and bounces. Weight changing target limit dependent are examined. ALABAMO can perform best in power use separated from objective function (OF0) in any case passes on less packages due to deferral. Regardless, executing ALABAMO in RPL will be the best choice because of dull showing up. In IoT orbited network, TA-OF can turn out best for RPL, it can change geography and bundle transparent degree. CA-OF has high throughput, pack development degree showed up diversity corresponding to objective function (OF0). The current strategies for pushing toward load changing in RPL give insufficient weight evolving. Evaluating the procedures anticipated for load balancing in RPL assist with understanding tremendous bits. The game plan measure rules of the show and the burdens of as far as possible.

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