



# Adaptive Load Balanced Routing in IoT Networks: A Distributed Learning Approach

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## ABSTRACT

Facilitating large-scale load-efficient Internet of things (IoT) connectivity is a vital step toward realizing the networked society. Although legacy wide-area wireless systems are heavily based on network-side coordination, such centralized methods will become infeasible in the future, by the unbalanced signaling level and the expected increment in the number of IoT devices. In the present work, this problem is represented through self-coordinating for IoT networks and learning from past communications. In this regard, first, we assessed low-complexity distributed learning methods that can be applied to IoT communications. We presented a learning solution then, for adapting devices' communication parameters to the environment to maximize the reliability and load balancing efficiency in data transmissions. Moreover, we used leveraging instruments from stochastic geometry to assess the behavior of the presented distributed learning solution against centralized coordinations. Ultimately, we analyzed the interplay amongst traffic efficiency, communications' reliability against interference and noise over data channel, as well as reliability versus adversarial interference over feedback and data channels. The presented learning approach enhanced both reliability and traffic efficiency within IoT communications considerably. By such promising findings obtained via lightweight learning, our solution becomes promising in numerous low-power low-cost IoT uses.

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## 1. Introduction

Recently, distributed computation in wireless networks attracted a huge deal of attention, particularly in the evolving pattern of the Internet of Things (IoT) communications in which IoT tools are armed with self-regulating process, storage, and communication abilities [8]. The main idea is that instead of transferring all raw information straightly crosswise a high cost (multi-hop), wireless network normally associated with high load-efficient [1]. These nodes can cooperate and communicate to each other to obtain their purpose [7]. Regarding the characteristic features of IoT, such as Being IP-oriented, large scale, and generally stateable, some standardization efforts particular by IoT have been made via the Internet Engineering Task Force (IETF). One of the relevant IETF working groups is Lossy Networks (LLN) and Routing Over Low power. As the term infers, this class is concentrated on routing the Low power and Lossy networks (LLN) such as IoT [2]. Nowadays, IoT systems are

armed with application profiles and protocols prepared for large-scale deployments [9].

The links and connectivity between sensing-devices (nodes) scattered for monitoring a particular phenomenon resulted in the proposal of the WSNs idea after the Internet of Things (IoT). By combining sensing-tools with other heterogeneous network systems such as LiFi, WiFi, and LTE, the array of services can be significantly expanded for decision-makers and public users in critical safety uses. Though, various design aspects should be incorporated into the routing protocol to realize the IoT paradigm including the limited-energy constraints, a low processing power, and short communication range between geo-located objects. Various attempts have been made within the studies to present lightweight solutions for the IoT paradigm and save energy [14, 15].

The network nodes are armed with communication ability in IoT uses, which can be communicated with other nodes, objects, or individuals. The applications of IoT include transportation [17], smart environments [18], and surveillance [16, 19]. In most of IoT applications, messages may be required to disseminate to some specific nodes via multicast transmissions. Multicast pathways (creating a multicast tree) are made via a multicast routing

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protocol, from a multicast source node to multiple destinations. Then, a packet can be sent by the multicast source node to simultaneously multiple destinations [28].

Among these issues, this paper is focused on the load-balancing complexity of the currently standardized IPv6 directing protocol for LLN, named RPL [3]. Optimizing the routing outline for converge cast traffic pattern. RPL is a distance vector protocol initiating from a border router. A Destination-centered Directed Acyclic Graph (DODAG) is made by RPL utilizing one or several metrics [10]. DODAG is created by taking into account the link costs, node features and an objective function [11]. Rank creation for each node on the DODAG is performed via the objective function [4, 5]. Different types of traffic are supported like point-multipoint, multipoint-point, and point-point [12]. The rank must severely increment monotonically from the root towards the DODAG leaves to have loop-free topology [13].

In this work, an improvement is proposed in RPL, by utilizing the distributed learning approach, where each node's Information Option (DIO) message is distributed by each node to its adjacent nodes. Hence, DIO messages involve the data like the DODAG recognizer, the objective function (Load balancing) metrics, the node's rank, or the metrics utilized for the pathway computation. After getting the DIO message, the adjacent node can adjust its own rank in terms of the nearby rank. Therefore, the DODAG is constructed in broadening wave fashion. For back propagation of the routing data from leaf nodes to the roots, destination Advertisement Object (DAO) messages are utilized.

## 2. Related works

Numerous studies have been performed on the types of adaptive routing in IoT and Objective functions (OF) such as time delay, energy-consuming, and load balancing. Nevertheless, inclusive research rarely exists on distributed learning in routing so far. In this section, some papers are introduced regarding routing based on context information [6].

Kumar, A. and Hariharan, N. [1] presented and investigated the behavior of an effective data collection and reliable data delivery outline CCR for an arrangement setup, in which data obtained by the IoT network endpoints like sensors should be traversed over wireless lossy links toward the other endpoint that is the host for the IoT usage. Particularly, CCR is a distributed method considering the traffic reducing gain obtained from content-centric data combination for routing traffic over consistent communication links via incorporation of link quality data. Regarding a message's content, an individual routing entry is constructed by each node for every content kind through running the suggested new objective function.

A brief explanation was provided by Zhang, L., Zheng, Wang, Z., Z. and Wang, J [20] regarding RPL and some associated research while pointing out some of its drawbacks and proposing three RPL-based multipath protocols. The overhead, end-to-end delay is reduced by the first protocol ELB, and packet delivery rate is increased in comparison with original RPL. A faster local repair mechanism is proposed by the second protocol FLR, which also reduces overhead and increases the packet delivery rate. However, it has a disadvantage including the increased end-to-

end delay. It is resultant from the increased number of packet and the hoop to transmit packet to root.

An event-triggered DCL-RBFN algorithm and a DCL-RBFN algorithm were proposed by Xie, Jin, et al. [21] for solving distributed learning problems. The traditional learning problems are reformulated as equivalent distributed optimization problems by decomposing centralized learning problems into a set of sub-problems with consensus constraints. Hence, they can be solved via individually processing and local communication on subsets. It is indicated that the suggested algorithms converge to the equivalent centralized solution. The presented DCL-RBFN algorithm accesses distributed data over the network and exchange local information iteratively to make an overall learning algorithm. The estimations of the local RBF output weights are exchanged between the neighbors at every iteration. A discrete-time version of the distributed optimization model was also investigated for guaranteeing the proposed algorithm's convergence. An elastic DCL-RBFN algorithm was presented for scenarios for adding novel data or removing outdated data over the network at the initial phase.

Bhat, Archana, and V. Geetha [22] proposed a detailed survey on different routing protocols for Internet of Things and different areas are listed concentrated for bringing superior behavior in IoT. Load balancing, security, and multipath routing are the main areas of concern for routing in Internet of Things.

Kim, Hye-Young [23] implemented a load-balance outline via Loadbot measuring network load and processing structural configuration. They analyzed a large quantity of user data and network load and applied Deep Learning's Deep Belief Network technique. A neural load prediction algorithm is processed by this scheme in terms of Deep Learning's Q-learning technique and a neural pre-ensembling to obtain efficient load balancing in the IoT.

Chen et al. [24] focused on adaptive load-aware and congestion control problems for sensor nodes in WSNs. They also offer a distributed congestion control protocol, the ALACCP, for adaptively assigning a proper forwarding rate toward potentially jammed sensor nodes for mitigation of the congestion load.

Ullah, R., Faheem, Y., & Kim, B. S. [25] presented a dynamic parent node selecting mechanism in RPL in AMI networks for smart metering, taking into account both queue utilization and residual energy. At first, we investigated the adjacent nodes' residual energy to prevent inconsistencies and routing loops within the DODAG. Average PDR and power consumption is assessed in the best and worst channel circumstances for the RX level of 80% and 40%, respectively. Then, we took into account the queue use of the adjacent nodes to prevent network congestion.

BEAR was proposed by Javaid, N., Cheema, S., Akbar, M. [26] that is an adaptive routing protocol. It uses the location information, chooses the neighbors, the successor and facilitating nodes in terms of the cost function value and, ultimately chooses the forwarder node, one with residual energy over the network's

average residual energy. Based on the simulation results, it was indicated that BEAR enhanced the network lifetime by about 55%.

Seyfollahi, A. and Ghaffari [27] presented a light-weight but effective solution known as QU-RPL to obtain load balancing by permitting each node to choose its parent node in terms of the queue use of its adjacent nodes and their hop distances to the border router. Moreover, they assessed the QU-RPL performance via extensive tests on a real testbed compared to the TinyRPL, and demonstrated that the packet loss problem is highly alleviated by our proposal at queues, thus obtaining considerable enhancement in end-to-end packet delivery performance.

Al-Shdifat, A. and Emmanouilidis, C [28] studied IoT from both conceptual and historical perspectives since the subject was developed into several dimensions. Relevant areas like pervasive computing, ubiquitous computing, and context awareness become the vital part of the IoT. Since it is associated with comprehending the alterations in the environment, and makes it possible to perform and consequently respond. It was the first stage for intelligence in the IoT. Comprehending context and thus by acting needs learning, hence, numerous machine learning techniques were provided and adapted in this regard. Since the number of devices and sensors increments continually at an extraordinary rate, flowing data from the IoT was turned into a main subject. For gathering, processing, managing, and analysis of the data, novel approaches and methods are required since the features of data including volume, veracity and, variety dimensions are entirely different from the conventional data. it is now known as the “big data” problem, and the IoT data have quickly been turned into the IoT big data.

### 3. Methodology

Our suggested RPL routing protocol is categorized as Content-Centric in terms of Distributed learning. Distributed Learning is a famous WSN technique in routing protocol utilizing on-demand queries or interests for requesting data from the adjacent nodes.

When a node joins a DODAG graph and if it receives a DIO message, it can process it through three ways:

- 1) Removing the DIO package because of some RPL criteria.
- 2) Processing the message in order for maintaining its location inside the network
- 3) Improving its location by achieving a lower rank inside DODAG.

Whenever a node reduces its rank, it should remove all parents having a lower rank than its new rank from its list of parents. By this action, it prevents formation of a loop in the network. After the end of this step, each node has a default route towards the root and it can send its data packages to the root.

As it will explain in the present simulation result the CCR-based RPL routing method has a high efficiency in data recognition and aggregation in the internet of things (IoT) network. Now, by utilizing the content-based RPL method in the direction of data

aggregation rate, the number of live nodes, correct data transfers, energy consumption, and the balance created in the network are compared with those of the ordinary RPL method.

The characteristics of the simulation used in the present paper are given in table 1:

**Table 1:** Characteristics of the simulated network

Parameter	Value
Area of the network	800 m × 800 m
Node numbers	50
Transfer range	100 m
Load size	512 Bytes
Packet transfer rate	25 KB
Simulation numbers	20

In the present paper, in order to increase the efficiency of the routing in IoT network, a content-based system is presented. In this method, each node uses the root-inquiry packages to recognize the parent nodes in order for being aware of the number of packages arrived to the root. Then, using this awareness, it calculates the level of confidence for the route provided by the parent. If the parent is malignant and the level of confidence for calculation of the parent node is lower, the considered node selects a parent having a higher level of confidence among its candidate parents. With such method, each node may easily avoid the malignant nodes. By routing the data correlated with intermediate relay node in order for process, a higher data collection ratio may be obtained. Hence, it effectively reduces the network traffic rate. As a result, a significant delay reduction in the data transfer may be acquired. In addition, extra data transfers may be annihilated after data collection which causes reduction in energy consumption merely in wireless communications and consequently, the energy consumption of the battery is saved.

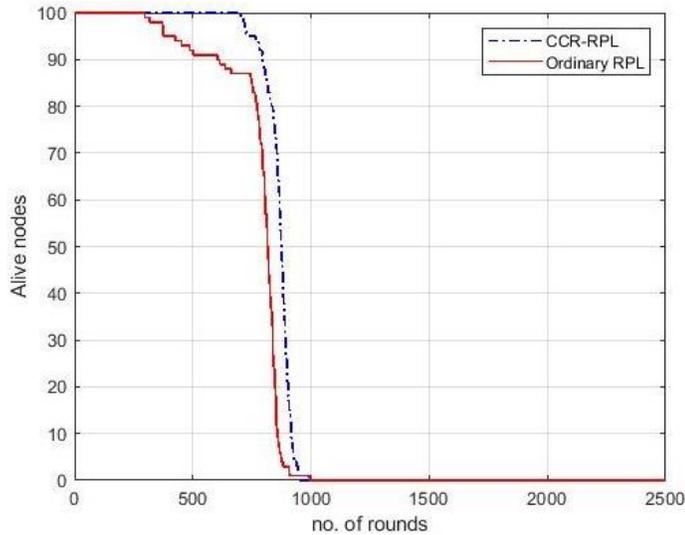
### 4. Results and Discussions

For evaluating our protocol, in our study, CCR-based RPL with MATLAB Simulator was simulated, an extensively utilized simulator for IoT. Here, a comparison is made between CCR-RPL and ordinary RPL. We adjust MRHOF as the OF of Ordinary RPL, and the protocol factors are tuned based on the CCR-based RPL ones (Table 1).

At first, the comparison is based on the queue loss ratio. Figure. 1 represents two protocols, under various traffic loads with altering traffic load (increasing). The results indicate that by the CCR-based RPL, the numbers of the live node is incremented within the network. However, another key feature of Figure 1 represents the worst case of the queue loss ratio within the nodes in various traffic loads. This is interpreted as the capability of CCR-based RPL in making a more balanced DODAG in terms of the network load.

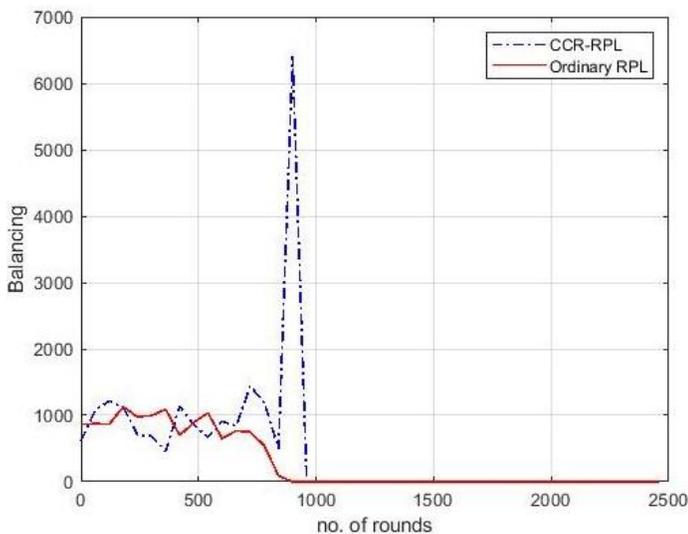
The simulation test was performed 20 times against the proposed protocol and RPL for every network size. The average results of the 20 runs represented the values provided in comparing the confidence level aspect. The simulation focused on comparing the load balancing between the two protocols for supporting the

better load balance within the nodes provided by our proposed routing protocol. We determined the nodes' energy confidence level followed by ending the simulation course.



**Figure 1:** Comparison between the number of the live nodes after sending and receiving the data.

The simulation was carried out with various packets within the range of 0-80 supporting the more efficient load balancing provided by our protocol compared to the directed diffusion irrespective of the size. Figure 2 represents the simulation outcomes comparing the standard deviation of all nodes' energy levels for the proposed protocol and directed diffusion.



**Figure 2:** Comparing the dominating balances on the system

These simulation tests indicated that despite the high difference, the suggested protocol (CCR-RPL) balanced the load more equally among nodes compared to the normal RPL

The dominated balancing is higher for the CCR-RPL than regular RPL, which has a highest rate (pick point) during increasing numbers of simulation test also would be higher than the peak for normal RPL as illustrate in Figure 2. In which the load on the network is biased owing to the incidence of localized

environmental information like traffic congestion. Then, we assess the possibility of distributing the load over the network through local data exchange.

## 5. Conclusion

This study deals with the challenges in RPL routing protocol under dynamic and heavy load while concentrating the Energy and network lifetime. We found that Ordinary RPL cannot effectively control the dynamic and heavy loads. For solving the problem, a load balancing and context-aware protocol were suggested in the present work, considering the rank of a parent-chain prior to choosing the final parent of the chain as the considered parent for a node. Therefore, we attempted to balance the load in the network. In the present work, the residual queue as well as the candidate parents' energy level were considered. Moreover, we hindered the problem of rushing toward an appropriate parent making a high control message rate and instability problems for the network. We assessed our protocol in MATLAB in various situations proving that CCR-RPL significantly outperforms RPL, while not impressing a high overload for the network.

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