



Performance Analysis of RPL for Low Power and Lossy Networks: A Survey

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Abstract— *The Low Power and Lossy Networks (LLNs) has aroused interest in research areas. LLNs include Wireless Sensor Networks (WSNs), Power Line Communication (PLC) networks and Wireless Personal Area Networks (WPANs). As LLNs are lossy networks routing in LLNs is of remarkable concern. The Routing Protocol for Low power and lossy networks, i.e., RPL is most widely used protocol for LLNs. RPL is a simple distance vector routing protocol which makes use of IPv6, reduces memory usage and also depend on fundamental routing and data forwarding techniques but it may meet very low delivery rates, due to selection of not only long but also unreliable links. It also does not regulate link estimation process. In this survey paper we provide an in-depth analysis of RPL and design choices that generate the unreliability issues in RPL.*

Keywords— *Low Power and Lossy Networks (LLNs), Wireless Sensor Networks (WSNs), Routing Protocol for Low power and lossy network (RPL), low delivery rate, link estimation.*

I. INTRODUCTION

The International Engineering Task Force (IETF) which is an international open community of network operators, designers and researchers described the Low power and Lossy Networks (LLNs) having following distinguishing features:

1. LLNs are “constrained” networks that are composed of many low-cost embedded devices with limited power, memory and processing resources.
2. LLNs employ a variety of low-power communication technologies [e.g., Low-power WiFi, and power line communication] which are typically affected by varying loss characteristics and connectivity.

LLNs additionally indicate the connections which are not restricted to two endpoints. This includes Point-to-Multipoint (P2MP) or Multipoint-to-Point (MP2P) connection patterns. These networks are also known for their asymmetric link properties. Due to their abilities, LLNs are increasingly deployed in many application domains that include home automation, industrial monitoring, smart energy metering, and urban sensing. The unreliable nature of the communication in the context of networks is referred to as being lossy and as the name suggests LLNs are lossy networks. This “lossyness” may be transient and unpredictable. The routing in LLNs should be self-manageable to a large extent and be able to repair itself without requiring manual intervention. So Routing in LLNs should be aware of lossy links and treat this as input requirements for design. The routing protocol design in this kind of network should be responsive to how much data a network can handle, the devices capabilities and the speed [1]. Hence Efficient Routing in LLNs must be taken into consideration. There is an impact of wireless lossy links on the overall reliability, power efficiency and maximum achievable throughput [2]. Lossy Links affect the power consumption due to packet broadcasting and re-transmission. The different routing protocols used in LLNs are 6LowPAN and RPL. In order to achieve requirements and challenges in LLNs, the Internet Engineering Task Force (IETF) ROLL Working Group has designed a routing protocol, called RPL [3]. The main goal of RPL is to provide efficient routing paths for various connection patterns in LLNs.

LLNs and, in particular, WSNs are rapidly emerging as a new type of distributed systems, with applications in different areas such as industrial and smart buildings, home automation, medical and environmental monitoring, traffic management, etc. However, to achieve a reliable communication, to guarantee a high delivery ratio and to be at same time energy efficient requires special mechanisms realized at the network layer [4]. Wireless Sensor Networks consists of embedded devices that can collect the data, process and communicate with each other. WSN consists of distributed autonomous devices which have limited power, memory and processing resources [2]. This limits all the aspects of their communication capabilities, architecture and construction.

II. RPL: ROUTING PROTOCOL FOR LOW POWER AND LOSSY NETWORKS

RPL is IPv6 distance vector routing protocol that builds Destination Oriented Directed Acyclic Graph (DODAG) from nodes over a physical network. RPL is designed using a various routing metrics and policies that satisfy the routing requirements of crucial applications, such as building automation, industrial automation, etc [5]. The design principles of RPL are to:

1. Reduce memory usage (e.g., the size of routing tables)
2. Rely on simple routing and data forwarding techniques
3. Lessen routing signaling.
4. Distribute compact routing information to support link layer technologies with confined frame size.
5. Efficiently discovered links and peers in order to be acceptable for networks that do not have pre-defined topologies.

There are three different types of nodes in RPL network. The first type are root nodes that offer connectivity to another network. The second type are routers which broadcast topology details to their neighbors. The third type are leaf nodes [6]. RPL supports three different traffic patterns : Multipoint to point traffic (MP2P), point to point traffic (P2P) and Point to multipoint traffic (P2MP) [7]. It also quickly constructs and distributes routing knowledge at the nodes, efficiently conforming to topology changes which makes it capable candidate for routing in LLNs [8].

The DODAG constructed by RPL is a logical routing topology assembled over a physical network to meet definite criteria. Each and every RPL node has a rank associated with it which is computed by an Objective Function (OF). The DODAG formation process is done using rank. Rank is a value deciding the path cost to the root that a node provides. DODAG lessen the path cost from a node to the root node. Root has the lowest rank in the DODAG.

A. Objective Function (OF)

In [5], two OF implementations are assessed. One using Expected Transmission count (ETX) as link metric and the other using Hop Count (HC) in Rank calculation.

In ETX based OF, nodes choose the parent which has the minimum rank and ETX value. Each node computes the ETX to candidate parents and selects the one with lowest overall ETX to the root. ETX is the number of transmissions that a node should have to successfully send a packet to destination node. ETX can be computed as below:

$$ETX = 1 / (DF * DR) \quad [9] \quad (1)$$

where DF is the probability of receiving packet by the adjacent nodes and DR is the probability of receiving acknowledgement. Node C computes its rank as following:

$$R(C) = R(P) + ETX \quad (2)$$

where R(P) is the parent rank and ETX is the Expected transmission count to node P. After that node C calculated R(C), will choose node P as parent if R(C) differs with the computed previous one more than a described threshold.

Hop count is the number of nodes that a packet should pass to reach the destination. In HC based OF, nodes try to have the less intermediate nodes to root and every node evaluates its rank upon receiving the parent rank. Rank is the aggregation of parent rank and DEFAULT_MIN_HOP_RANK_INCREASE which is described 256 in RFC (6550) [10]. So we define rank computation in HC OF as following:

$$R(C) = R(P) + DEFAULT_MIN_HOP_RANK_INCREASE \quad (3)$$

where R(C) is Rank of the node and R(P) is rank of the node parent. Node C chooses the parent node that lowers R(C).

B. DODAG Formation Process

RPL defines three different type of control messages for topology maintenance and data exchange. The first one is DODAG Information Object (DIO) which is the chief source of routing control information. The second one is Destination Advertisement Object (DAO) control message which is used to describe downward routes. And the third one is DODAG Information Solicitation (DIS). If the node does not receive DIO packet it will deliver DODAG information solicitation control message to ask its adjacent nodes for sending DIO.

The various steps in DODAG Formation Process are:

1. The root sends DIO messages to its neighbors.
2. Compare the rank of current parent of the node with the rank in DIO.
3. Based on OF and parent's rank, compute new rank of the node.
4. Compare new rank and previous rank of the node.
5. If the new rank is less than previous rank, then add current parent node to parent list, select the sender node as preferred parent and forward DIO with computed rank to neighbors.
6. If new rank is greater than previous rank, add sender node to parent's list.

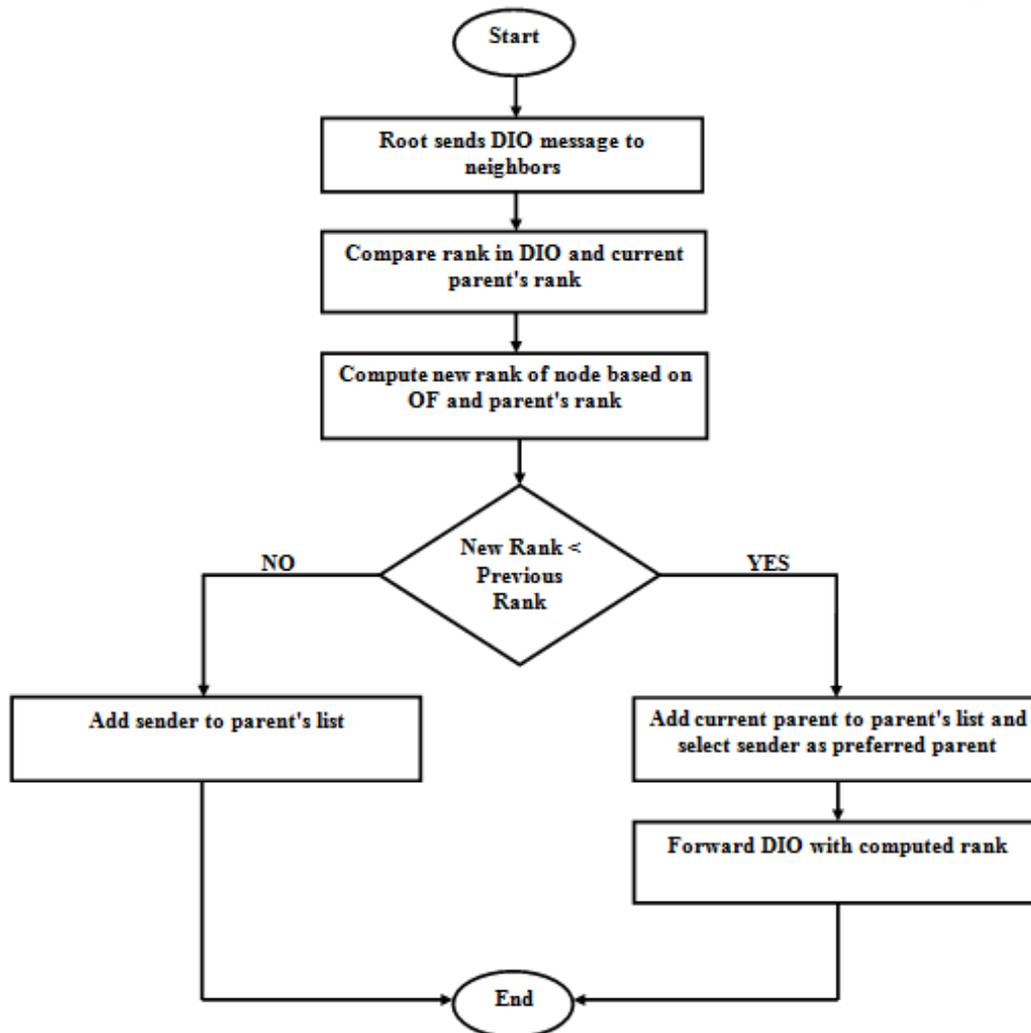


Figure 1. DODAG Formation Process

C. Issues in RPL

RPL may undergo low delivery rates, specifically in large-scale deployments. One of the most significant reason of RPL unreliability is that RPL nodes may utilize network paths which are long and unreliable due to limited and imperfect knowledge of neighborhood data. The nodes in a network are battery powered so energy conservation is also an important factor which is often neglected by RPL.

III. CONCLUSIONS

The RPL experiences high packet misfortune and low delivery rates. Packet misfortunes do not simply increase with path length. As already stated, RPL nodes may use network paths with long and unreliable links due to limited knowledge of neighborhood information. This also leads to energy wastage. So there need to address these aforesaid issues with a better and perfect implementation of RPL that effectively observe and study the quality of an individual link, more learned next-hop determination, improve the packet release rate and obtain the reliability in the network by eliminating bad link.

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