IJCSE International Journal of Computer Sciences and Engineering Open Access
Research Paper Vol.-7, Issue-2, Feb 2019 E-ISSN: 2347-2693

Simulation of Routing protocol for Low power and Lossy Networks with Cooja Simulator

Nithya Lakshmi N[1*], M. Hanmandlu[2]

[1,2]Computer Science and Engineering, MVSR Engineering College, Osmania University, Hyderabad, India

[*]*Corresponding Author: nithyasanthanam919@gmail.com*

DOI: https://doi.org/10.26438/ijcse/v7i2.1620 | Available online at: www.ijcseonline.org

Accepted: 10/Feb/2019, Published: 28/Feb/2019

***Abstract*—** Low power and Lossy Networks now regarded as one of the most extensive study areas are comprised of a huge number of constrained nodes with restricted power, memory and processing facility. Besides, nodes in these networks consistently function on batteries and shows evidence of unpredictable communication often. Routing in such constrained networks is extremely tough since the available protocols were not suitable for low-power and lossy networks and thus the Internet Engineering Task Force (IETF) ROLL Working Group proposed an IPv6 based Routing Protocol for Low power and Lossy Networks called RPL capable of forming network routes issuing information about routing among nodes and adapting to network topologies. This paper mainly focuses on the simulation study of routing protocol for low power and lossy networks with Cooja simulator.

***Keywords*—** WSN, RPL, Contiki, Cooja, LLN.

I. INTRODUCTION

The usage of low power wireless devices that are greatly resource constrained due to their tiny size, less power and low cost has increased rapidly and became a part of our day to day life. They are referred to as low power and lossy networks (LLNs) that includes wireless sensor networks (WSN) made up of a large number of scattered nodes able to gather and process data from environment in addition to communicating to each other. Nodes forward data packets to destination as well route data packets to other nodes. Also, low power and lossy networks checks to find alternative paths to a destination with various links mentioned by a metric. IPv6 has become a benchmark for low power networks where a large number of devices can be connected when compared with IPv4. 6LoWPAN, an IP based technology for low power wireless personal area networks bridges gap between low power devices and Internet by combining features of IEEE 802.15.4 and IPv6 [2]. These networks mainly depend on the routing protocol selected such that the major responsibility of it is to create quick decisions in forming routes from source to destination. Since the time 6LoWPAN is specified, routing in these networks considered to be a challenge and to address this, IETF proposed IPv6 Routing Protocol for Low power and Lossy Networks (RPL). RPL protocol is used in low power and lossy networks as they are able to build up network routes, adjust to topology changes in the network and support multi-hop routing. Contiki is an operating system which is open source and are specifically designed for low power devices. The main objective of this paper is to simulate the routing protocol for low power and lossy networks with cooja simulator and study how the protocol forms the network routes by making routing decisions in a constrained low power and lossy networks.

The remaining sections of paper are organised as follows: Section II briefs related work corresponding to this study. Section III presents a detailed study of RPL for LLNs using Cooja Simulator of Contiki operating system. Section IV discusses simulation results of RPL using Cooja simulator. Finally, Section V gives conclusions of the paper.

II. RELATED WORK

In recent years, major research work is devoted to the simulation and experimental evaluation of RPL. A study is conducted in [9] on performance analysis of RPL using Cooja simulator of Contiki operating system. A simulation study of RPL on Destination Oriented Directed Acyclic Graph (DODAG) abbreviated as RPL DODAG is made in [15]. A method is presented in [18] to improve performance of RPL in dynamic networks. A fuzzy based objective function is proposed in [19] so as to address the pitfalls of the standard objective functions associated with RPL. Moreover, the need for RPL is emphasized in terms of reliability, end-to-end packet delivery and energy. The dynamic simulation is not addressed in the literature. The present work is aimed at filling up this gap.

III. ROUTING PROTOCOL FOR LOW POWER AND LOSSY NETWORKS (RPL)

A. RPL Overview

As mentioned above RPL is an IPv6 based distance vector routing protocol intended for low power and lossy networks. RPL works on top of IEEE 802.15.4 physical and data link layers [1]. The nodes in an RPL network organize as a Destination Oriented Directed Acyclic Graph (DODAG) which is shown in figure 1. DODAG is formed based on an objective function which describes selection of nodes and routes in an RPL instance using routing metrics. The routing metrics can either be link metrics or node metrics where the rank of a node is defined by an objective function based on node position and link metrics.

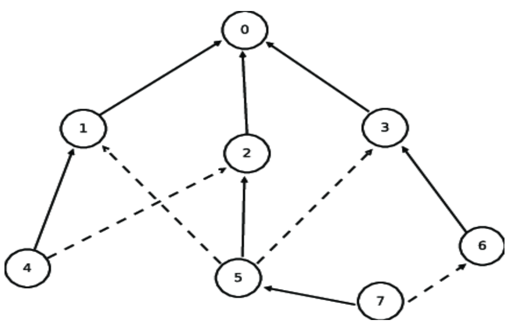

Figure 1. RPL DODAG Topology

The RPL network nodes can be categorized into any one of the three types with the first one as low power and lossy border router (LBR) also referred to as root node that acts as a gateway between low power devices and Internet facilitating the construction of DODAG, the second one as router not capable of constructing DODAG but capable of forwarding and generating data traffic and the third one as host which can only generate data traffic but cannot forward.

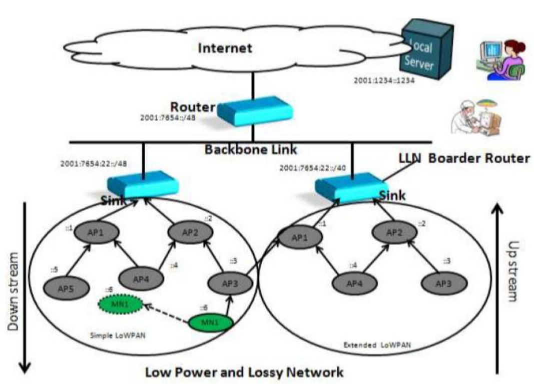

Figure 2. LLN Architecture

Figure 2 shows the architecture of low power and lossy networks. RPL supports three different traffic patterns: point to point (P2P), point to multipoint (P2MP) and multipoint to point (MP2P) traffic [16].

B. RPL Control Messages:

RPL specifies three types of ICMPv6 control messages for both constructing and maintaining DODAG network topology [16]. They are : (i). *DODAG Information Object (DIO):* helps construct upward routes and also contains information about DODAGID, rank and objective function.
(ii). *DODAG Information Solicitation (DIS):* solicits DIO control messages from nodes previously joined in DODAG.
(iii). *Destination Advertisement Object (DAO):* establishes downward routes in DODAG. Table 1 shows RPL control messages and their codes.

Table 1. RPL Control Messages and their Codes

Code	Message Type
0x00	DODAG Information Solicitation
0x01	DODAG Information Object
0x02	Destination Advertisement Object
0x03	Destination Advertisement Object-Acknowledgement

C. Contiki OS and Cooja Simulator:

Contiki is an open source operating system targeting IoT devices with limited power, memory and processing capability [17]. It runs on low-power, low-cost and tiny microcontrollers and is used extensively to perform simulations of small to relatively large wireless sensor networks. Cooja is a simulator of Contiki operating system for emulating hardware platforms in case of non- availability of hardware devices [20]. Cooja simulator supports two Objective Functions: Objective Function Zero (OF0) and Minimum Rank with Hysteresis Function (MRHOF) in the implementation of RPL. In this study, MRHOF is used. Generally, Objective function is defined by an Objective Code Point (OCP) in DIO configuration option message.

IV. RPL SIMULATION AND RESULTS

A. RPL Protocol Contiki Simulation Setup:

RPL protocol is simulated in Cooja simulator under Contiki operating system impressed by its features compared to other simulators. Contiki operating system is used as it emulates the behaviour of real motes in simulation and the application is operated in Cooja simulator on Z1 Zolertia mote which is equipped with 8KB RAM, 16MHz MSP430 low-power microcontroller and 8MHz clock speed. The main objective of this paper is to analyse RPL protocol where the simulation has been conducted with 5 client nodes and one sink node emulated as Zolertia Z1 nodes. The network traffic is captured by enabling radio messages in Cooja simulator and saved as pcap files that can be analysed using Wireshark, a network protocol analyser. Table 2 gives Cooja simulation parameters considered in this work.

Table 2. Cooja Simulation Configuration Parameters

Parameters	Values
Operating System	Contiki
Simulator	Cooja
Radio Model	UDG model with distance loss
Mote type	Zolertia Z1
Sink node	1 node
Client nodes	5 nodes
Objective Function	MRHOF

DODAG in RPL is constructed and maintained by the root node using control messages and Figure 3 shows constructed DODAG topology using Cooja simulator where nodes communicate with each other using RPL control messages and arrows in figure shows data traffic direction. The root node multicast DIO messages to nearby nodes and based on objective function, preferred parent is selected. The nodes beyond radio range of root node communicate with it through multi-hop scenario.

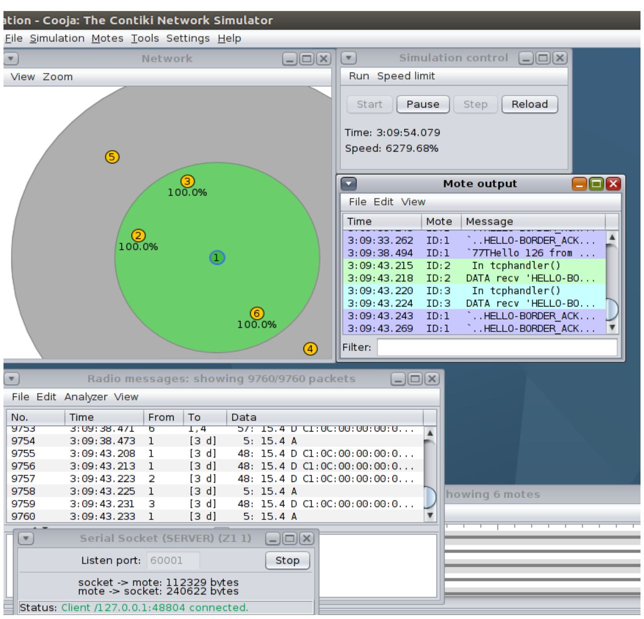

Figure 3. Construction of RPL DODAG using Cooja simulator

The routing table showing the path how nodes communicate with each other is shown in figure 4.

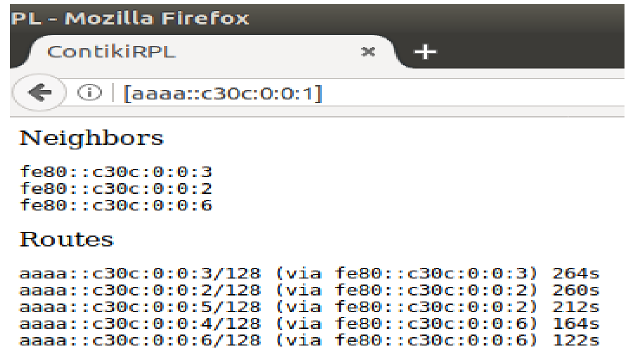

Figure 4. Routing Table

Radio messages as shown in figure 5 are enabled in simulator and saved as pcap files which are imported into network protocol analyser, Wireshark.

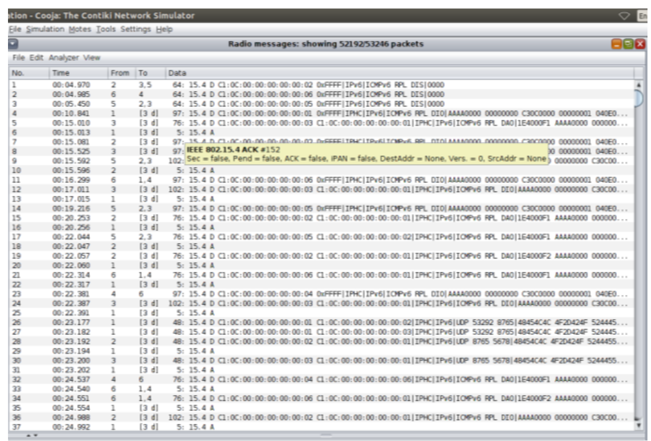

Figure 5. Radio Messages Enabled in Cooja simulator

In case if any node already joined in DODAG and selected as preferred parent in multi-hop scenario by any other node does not participate in network, the parent is selected based on the objective function and the corresponding routing path is chosen as shown in figure 6.

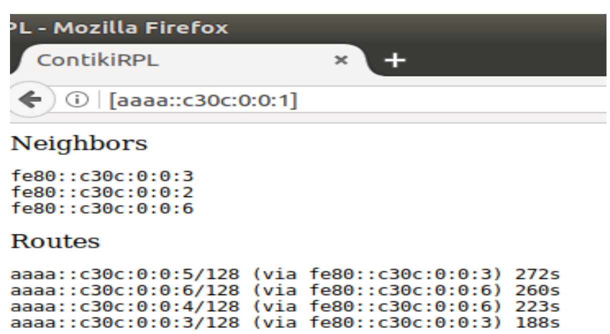

Figure 6.Routing in Cooja simulator

The wireshark traces of simulation presenting DIO base object with MRHOF chosen as an objective function indicated by an Objective Code Point (OCP) in configuration option of DIO message [1] is shown in figure 7. The MRHOF objective function uses ETX as a metric [21] whereas OF0 uses hop count as a metric.

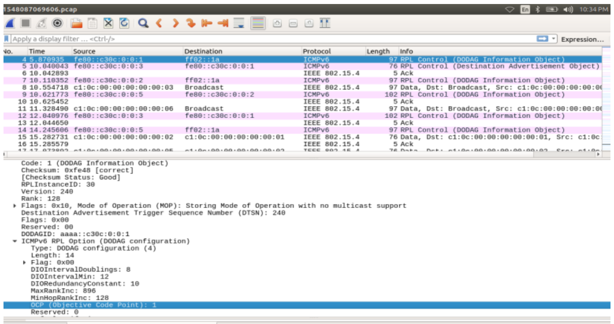

Figure 7. Wireshark traces showing DIO base object

The node willing to join DODAG sends DIS control message to neighbouring nodes. The nodes receiving DIO message from preferred parent send a DAO message in response to join the DODAG. The wireshark traces of simulation showing DAO base object and DIS base object are shown in figure 8 and 9 respectively.

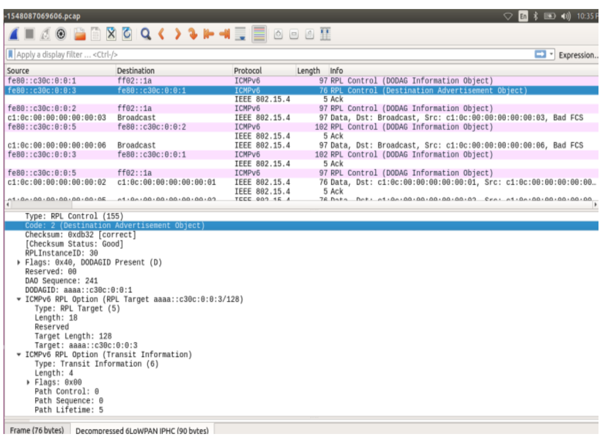

Figure 8. DAO Base Object

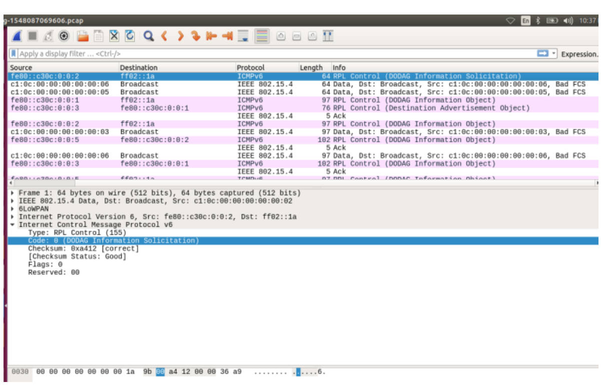

Figure 9. DAO Base Object

The network topology of nodes in low power and lossy networks changes periodically and is shown in Figure 10.

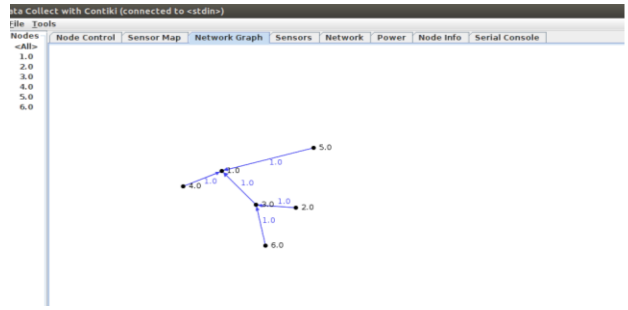

Figure 9. Network Graph

From the above results, it is clear that RPL makes intelligent decisions in forming routes in low power and lossy networks given the lossy links and constrained with limited power, memory and procssing capability.

V. CONCLUSIONS

Low power networks are rapidly increasing thereby demanding a good routing solution based on IPv6 addressing scheme to route vast data. RPL was proposed to address this issue where we are concerned with the simulation study of the protocol. The simulations are performed using Cooja simulator in Contiki operating system with MRHOF objective function employing ETX metric. RPL helps in building network routes undergoing topology changes. Based on the analysis of results, it is observed that RPL provides a good routing solution for LLNs.

REFERENCES

[1] T. Winter, "RPL: IPv6 routing protocol for low power and lossy networks," Internet Eng. Task Force, Fremont, CA, USA, RFC 6550, accessed: Sep. 2017.

[2] G. Montenegro, C. Schumacher, and N. Kushalnagar,"IPv6 over low-power wireless personal area networks (6LoWPANs): Overview, assumptions, problem statement and goals,"Internet Eng. Task Force, Fremont, CA, USA, RFC 4919, accessed: Sep. 2017.

[3] A Brandt and G. Porcu, "Home automation routing requirements in low-power and lossy networks," Internet Eng. Task Force, Fremont, CA, USA, RFC 5826, accessed: Sep. 2017.

[4] M. Dohler, T. Watteyne, T. Winter, and D. Barthel , "Routing requirements for urban low-power and lossy networks," Internet Eng. Task Force, Fremont, CA, USA, RFC 5548, accessed: Sep. 2017.

[5] J. Martocci, P.D. Mil, N. Riou, and W. Vermeylen, "Building automation routing requirements in low-power and lossy networks," Internet Eng. Task Force, RFC 5867.

[6] K. Pister, P. Thubert, S. Dwars, and T. Phinney, "Industrial routing requirements in low-power and lossy networks," Internet Eng. Task Force, RFC 5673.

[7] P. Levis, T. Clausen, J Hui, O. Gnawali, and J. Ko, "The Trickle algorithm," Internet Eng. Task Force, RFC 6206.

[8] D. Barthel, J. Vasseur, K. Pister, M. Kim, and N. Dejean, "Routing metrics used for path calculation in low-power and lossy networks," Internet Eng. Task Force, RFC 6551.

[9] T. Zhang, L. Xianfeng, "Evaluating and analysing the performance of RPL in Contiki," Intenational workshop on mobile sensing, computing and communication," pp: 19-24, 2014.

[10] Olfa Gaddour, and Anis Koubaa, "RPL in a nutshell: A survey," 2013.

[11] J. Wang, and H. Li, "Researching and hardware implementation of RPL protocol based on Contiki operating system," International Journal of Future Computer and Communication, Dec. 2014.

[12] Xun Yang, "The Application of RPL routing protocol in low-power wireless sensor and lossy networks," Sensors and Transducers, Vol . 170, Issue 5, May 2014, pp. 107-111.

[13] Iova, O., et al. "The love-hate relationship between IEEE 802.15.4 and RPL," IEEE Communications Magazine, pp: 188-194, 2017.

[14] Olfa Gaddour, Anis Kaubaa and Mohammed A, "Quality-of-Service aware routing for static and mobile ipv6 based low-power and lossy networks using RPL," Adhoc Networks, pp: 233-256, 2015.

[15] J.P Vasseur, and Adam Dunkels, "Interconnecting smart objects with IP- The next Internet", 2010.

[16] J. P. Vasseur, N. Agarwal, J. Hui, Z. Shelby, P. Bertrand, and C. Chauvener, "RPL: The IP Routing protocol designed for low-power and lossy networks"", Internet Protocol for Smart Objects (IPSO) Alliance, April 2011.

[17] Contiki: The open source operating system for Internet of Things.

[18] Olfa Gaddour, Anis Koubaa, "Co-RPL RPL Routing for mobile low power wireless sensor networks using Corona mechanism," 9th IEEE International Symposium, pp: 200-209, 2014.

[19] Olfa Gaddour, et. al, "OF-FL: QoS-aware fuzzy logic objective function for RPL routing protocol," Proceedings of 12th International symposium on Modelling and Optimization in Mobile, Ad-Hoc and Wireless networks, pp. 365-372, May 2014

[20] An introduction to Cooja, https://github.com/contiki-os/contiki/wiki.

[21] O. Gnawali, P.Levis, "The Minimum Rank with Hysteresis Objective Function," Internet Eng. Task Force, RFC 6719.

Authors Profile

Nithya Lakshmi N is pursuing M.Tech (CSE) from MVSR Engineering College (MVSREC) affiliated to Osmania University (O.U) of Hyderabad, Telanagana. She has completed her B.E (CSE) from Hindusthan College of Engineering and Technology.

Madasu Hanmandlu (SM'06) received his B.E. degree in Electrical engineering from Osmania University, Hyderabad, India, in 1973; M.Tech. degree in Power systems from Jawaharlal Nehru Technological University, Hyderabad, India, in 1976; and Ph.D. degree in control systems from the Indian Institute of Technology (IIT) Delhi, New Delhi, India, in 1981. From 1980 to 1982, he was a Senior Scientific Officer with the Applied Systems Research Program, Department of Electrical Engineering, IIT Delhi. In 1982, he joined the Department of Electrical Engineering, IIT Delhi, as a Lecturer and became an Assistant Professor in 1990, an Associate Professor in 1995 and Professor in 1997. After retirement in 2014, he became an Emeritus Professor . Then he left IIT Delhi to become Professor in CSE Department at MVSR Engineering College, Nadergul, Hyderabad in 2015 and still working there as Professor.. His current research interests include fuzzy modeling for dynamic systems and applications of fuzzy logic to image processing, medical imaging, multimodal biometrics and surveillance.