Effect of Network Topology on RPL Performance Metric

Suneeta Mishra, Vidushi Sharma and Neeti Gupta

June 9, 2023

Effect of Network Topology on RPL performance metric

Suneeta Mishra, Dr. Vidushi Sharma and Dr. Neeti Gupta
School of ICT
Gautam Buddha University
Greater Noida, India
Email: sun.mishra1978@gmail.com

***Abstract*—** Internet of things is defined as the collection of networked objects, devices equipped with sensors, actuators and processors, capable of communicating with each other and making decisions on their own, that work together to serve a meaningful purpose.
When a number of sensor nodes work together, they form wireless sensor network. The network constitute from these nodes is energy constrained as it is operated by the battery, memory constrained and limited with processing speed. So, the routing protocol needed for such type of network should be such that it can full fill the requirement of such type of network. According to the IETF working group RPL(routing protocol for low power and lossy network) `is the best reliable and efficient protocol for wireless sensor network.. this paper present how the topology along with network size affect the performance metric of RPL.
Contiki 3.0(Cooja simulator) provides four types of facility to form network topology i.e. random, linear, manual and elliptical/Ring[11] This paper represent the comparative analysis among Random, Linear, Ring and Tree topology also on the basis of performance metric. so that the overall design of the network can be improved. Cooja simulator is used to analyze the result and it is found that random topology provides better result in terms of packet delivery ratio .In Linear topology power consumption increases with network size. Rt-metric remains almost same for 10, 15 and 20 node networks

***Keywords*—** wireless sensor network, RPL, contiki, cooja simulator, network, topologies.

I. *Introduction*

In recent years wireless sensor becomes a part of our daily life. It can be used in detecting ambient conditions (temperature, sound, light etc.), Distributed computing (weather prediction, forest fire etc.), fault detection and diagnosis (huge structure, machinery etc.), health care and defense operation. It will become more popular when 5G and 6G come into existence. Currently the internet involves the process of connecting machines, software and things in our surroundings.

Although wireless sensor network has the following characteristics i.e. Self-Adapting, Self-Configuring, Dynamic and Unique Identity etc. but the main issue with sensor network is power supply as sensors operates with battery that has limited life time and it is not a simple task or almost impossible to replace the battery. As the more wireless devices will connect in to the wireless sensor network, energy consumption will increases that destroy the network efficiency due to die out of the sensor nodes.[1]

There is another challenge with wireless sensor network i.e. processing speed, low data rate and bandwidth. Although various routing protocol designed by the various researcher for wsn like, that are classified as fixed –allocation, demand –based and contention based,[2] but unable to full fill all the requirement of wireless sensor network. RPL is find suitable routing protocol for low power and lossy network. It supports 802.15.4, ZigBee and Bluetooth along with support IPV6 that gives the facility to connecting a large number of wireless devices in the wsn.

II. Overview of RPL Protocol

RPL is a standard Routing Protocol for low power and lossy networks, is the De facto Routing Protocol for the internet of things. This Protocol work on IP version 6. It would be represented in 128 bit[5]. RPL has contributed to the advancement of communication in the world of tiny, embedded networking devices by providing, along with other standard like ZigBee, Bluetooth and IEEE802.15.4. IETF consider the RPL as the standard Routing Protocol for Low Power and Lossy Network [8]and this protocol based on Tree like structure. The network topology organizes by RPL in the form of Destination Oriented Graph (DAG) and this graph is made from two or more Destination Oriented Directed Acyclic Graph (DODAG).

III. Characteristics of RPL

There are various characteristics in RPL which make it more efficient and suitable routing protocol than other protocol made for wireless sensor network.

A. *Capability to optimize and save energy*

To save the energy to make DODAG which avoid looping and several metrics and constraint aware for saving energy

B. *Capability to support traffic pattern other than unicast communication*

It is capable to support three types of traffic pattern (i) Point to point (ii) multipoint to point (iii) point to multipoint[7].

C. *Capability to run over link layer with restricted frame size*

Due to limited in Power source, able to add up the frame size for incoming data packets.

D. *RPL build a DODAG*

RPL creates different path to the different node. This path based on objective function firs one is objective function zero(OF0), based on the number of hops and another one is minimum rank hysteresis objective function (ETX), based on ETX(expected number of retransmission).this makes the path more reliable.

IV. RPL Topology

Network topology is used to connect sensor nodes in order to communicate information. Parameters that decides the quality of service of a network depends of implemented network topologies. Tree, Star , Mesh, Ring and Linear/ Grid and Random topology generally used in wireless sensor network[6]. each network topology has plays a significant role in different application field. some topologies are described below:

A. Tree Topology

This topology makes tree like structure .root node or sink node placed at the top and connected to parent node. Parent node connected to the child node. In RPL selection of parent node and child node depends upon the rank of the node from the root node. rank of the root node is 0 whereas parent node has the rank greater than root node but less than child node.

B. *Star Topology*

In this topology a single central node act as a root node and all other nodes are connected to it by single hop. It is a type of fully connected network.

C. Mesh Topology

Apart from transmitting its own data, each node act as a relay node for other nodes in this topology.in fully connected mesh topology each node is connected to other node where in partial connected mesh network, every node is not interconnect to other node.

D.Ring Topology

In Ring topology all nodes are connected to neighboring node in one direction including delay of n-1, where n is the number of nodes. In double ring network each node is connected to its immediate nodes as well as node with distance of two hops. It is fully connected point to point network.

E. *Linear/ Grid Topology*

In this topology each node is connected to its neighboring node in sequential chain manner. It can be grid type or bus type.

F. *Random Topology*

Sensor nodes deployed in an unplanned manner, the topology is called Random topology.

V. RPL Node Metric and Link Metric

Low power and lossy network use node –metric and link metric like other traditional network.[3]
Node Metric: Node state attributes Hop count and energy..
Link Metric: ETX, latency, throughput
Node metric and Link metric used to form and maintain the routes from source node to sink node by using objective function[10] i.e objective function zero(OF0) and minimum rank hysteresis objective function(MRHOF). OF0 use Hop count as metric, that is based on the rank of nodes [9] where as MRHOF uses ETX(expected retransmission) as metric[4]. Latency, throughput, Energy can also be taken as one of the metric of MRHOF.

A. Hop count

It represents the distance from sink node of source node. The rank of sink node is zero and as the distance of other nodes increases from sink node, its rank will increase thus in any DODAG the rank of parent node is always greater than the child node. In this manner route is formed in which node with lesser rank will act as parent node and send the information packets to the sink node coming from the child node.

B. *ETX*

It is the number of retransmission of packets by any source node to the sink node. If the value of ETX Increases it may be possible that the packet loss rate at that route is high even there is only single hop. For example if there are 3 intermediate link and the value of ETX is also 3 then the packet delivery ratio(measure of packet loss rate) will be 100% and if there are 3 intermediate link(hops), and the ETX value is 6 value of PDR (packet delivery ratio)will be 50% and if the ETX value is 12 then PDR will be 25%.

VI. Performance Metric of RPL

There are various parameters that decides the performance of RPL.

Packet Delivery Ratio (PDR)

The PDR can be described as the ratio of data packets that are actually received at the receiver end to those which were originally sent by sender. So, in other terms, it can also be defined as
PDR= Ri/Si
Where, Ri - number of packets received by the sink node,

Si – number of packets actually sent by the source or sender node.

A. Average power consumption

Power consumption is one of the most important parameter as the wireless sensor network is energy constraint. There are four mode in which power is consumed i. e normal operation of a CPU, low power mode, listen mode and transmission mode.

$Ptotal = Pcpu + Plpm + Plisten + Ptx$

B. Rt-Metric

It provides the path cost for a given path. It calculates the path cost on behalf of total number of hops, speed, latency, packet loss etc. by taken as input

Table 1: Simulation Parameters

Parameter	*Value*
Objective Function	OF0, MRHOF
Tx ratio	100%
Rx ratio	100%
Transmission range	100
Interference range	50
Mote start up delay	1000 sec
Topologies	Random, Linear, Tree, Ring

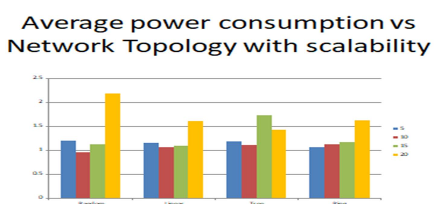

Fig.1: Average power consumption for different network topology and scalability

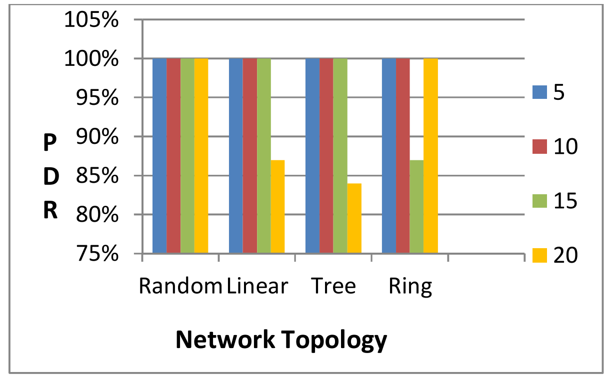

Fig.2: Packet delivery ratio for different network topology and scalability

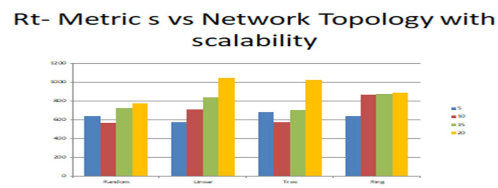

Fig.3: Routing metric for different network topology and scalability

VII. CONCLUSIONS

It is concluded that Random topology shows the best performance for 5 to 20 network size whereas Linear and Tree topology not suitable for 20 and above sensor node network in terms of packet delivery ratio. linear topology uses lesser power consumption whereas Random topology shows better performance in terms of packet delivery ratio. Linear topology shows increasing value of Rt-metric with network size.

References

[1] Watteyne, T., Vilajosana, X., Kerkez, B., Chraim, F.,Weekly, K.,Wang, Q., Glaser, S., Pister, K.: OpenWSN: a standards-based low-power wireless development environment. Trans. Emerg.

[2]. Li, B., Zhang, X.: Research of development in wireless sensor network routing protocols based on NS2. In: International Conference on Electronic and Mechanical Engineering and Information Technology, pp. 1913–1916. IEEE, Harbin, China (2011)

[3]. J. Vasseur, M. Kim, K. Pister, N. Dejean and D. Barthel, "Routing Metrics Used for Path Calculation in Low-Power and Lossy Networks", *document RFC 6551*, Mar. 2012.

[4] H. Lamaazi and N. Benamar, "comprehensive survey on enhancements and limitations of the RPL protocol: A focus on the objective function", *Ad Hoc Networks*, vol. 96, pp. 102001, Jan. 2020.

[5] Athraa J. H. Witwit and Ali Kadhum Idrees,‖ A Comprehensive Review for RPL Routing Proto col in Low Power and Lossy Networks‖, pp 50-66, 2018.

[6] M. B. Yassein., M. Yatim, M. Salaymeh, Y. Khamayseh, and W. Mardini. Optimal personal area network coordinator placement in grid topology. In International Conference on Mobile Web and Information Systems. Springer, Berlin, Heidelberg, Agust 2013, pp. 260-273.

[7] Jun Jiang and Yuhong Liu and Behnam Dezfouli,‖ A Root-based Defense Mechanism Against RPL Blackhole Attacks in Internet of Things Networks‖, Proceedings, APSIPA Annual Summit and Conference 2018, Hawaii

[8] T. Winter, P. Thubert, A. Brandt, J. Hui, R. Kelsey, P. Levis, K. Pister, R. Struik, and J. Vasseur, "RPL: IPv6 Routing Protocol for Low power and Lossy Networks," March 2011, Internet Draft, work in progress, draftietf-roll-rpl-19

[9] P. Thubert, "Objective Function Zero for the Routing Protocol for LowPower and Lossy Networks (RPL)," IETF RFC 6552, Mar. 2012.

[10] T. Winter, P. Thubert, A. Brandt, J. Hui, R. Kelsey, P. Levis, K. Pister, R. Struick, J. Vasseur, R. Alexander, "RPL: IPv6 Routing Protocol for Low-Power and Lossy Networks", IETF RFC 6550, 2012

[11] H. Ali, "A Performance Evaluation of RPL in Contiki". Master's Thesis, Blekinge Institute of Technology, Sweden, (ELnaz), pp. 5-85, 2012.

[12] Gupta, N., Pughat, A. & Sharma, V. A critical analysis of RPL objective functions in internet of things paradigm. Peer-to-Peer Netw. Appl. 14, 2187–2208 (2021). https://doi.org/10.1007/s12083-021-01180-9