An Analysis of Performance of Routing Protocol for Low Power and Lossy Network in Sparse Wireless Sensor Network

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Abstract: In this study we investigate Objective Functions and the most influential parameters on Routing Protocol for Low power and Lossy Network (RPL) performance in Sparse Wireless Sensor Network in the COOJA simulator of Instant Contiki (WSN Operating System) and evaluated RPL performance in terms of Energy, Packet Delivery Ratio, Average Transmitted and Received Power and Convergence Time for the Sparse Wireless Sensor Network.

Keywords: Wireless Sensor Network, Sparse, Packet Delivery Ratio, Transmitted and Received Power, LLN-Low Power and Lossy Networks.

I. Introduction

Wireless sensor networks are hastily becoming common in application areas where information is need to be collected and acted upon. By deploying a wireless sensor networks adds flexibility to the network and the cost of cabling can be avoided. One of the major issue in sensor networks is that wireless nodes most often need an energy source i.e. a local battery. So it limits the amount of energy available to the node and it affects the serviceable lifetime of the sensor network. In many application scenarios, replacement or recharging of power resources (e.g. battery) is costly or even impossible. Energy efficiency in sensor networks thus becomes a hot issue in wireless sensor networks.

(a) Sparse Network

In the context of network science, a sparse network is a network with less number of links than the maximum possible number of links within the same network. The study of sparse networks is a relatively new area primarily stimulated by the study of real networks, such as social and computer networks [1]. The number of links is varying from network to network, if the number of links is smaller than the maximum number of links, then it is a **Sparse Network**. Sparse connectivity can be identified in networks in which nodes are difficult to be linked. $L<L_{max}$ for $L=N(N-1)/2$; here 'L' is Links and 'N' is nodes. Most of the real networks are sparse [2].

(b) Overview of RPL

Routing protocol for low power and lossy networks (RPL) is IPv6 routing protocol for LLN designed by IETF routing over low power and lossy network (ROLL) group as a proposed standard. RPL is a distance vector protocol for the reason that linked state protocols have need of a noteworthy amount of memory (links state database, LSDB) which is not suitable for the resource constrained LLNs. RPL is a proactive routing protocols and start finding the routes as soon as the RPL network is initialized [3]. RPL is designed to meet the core requirements specified in [4] and [5].

RPL forms a tree like topology also called DAG. Each node/mote in a RPL network has a preferred parent which acts as a gateway for that node. If a node does not have an entry in its routing table for a packet, the node simply forwards it to its preferred parent and so on until it either reaches the destination or a common parent which further forwards it down the tree towards the destination [6]. The nodes in a RPL network have routes for nodes downwards the tree. It means the nodes nearer to the root node have larger routing tables saved in their memory.

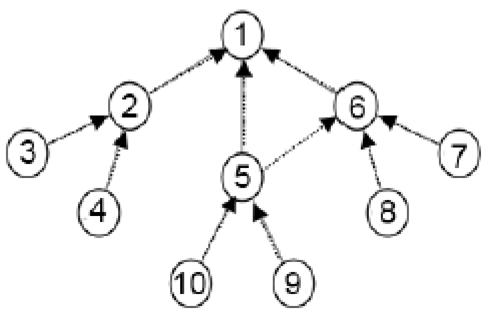

Figure 1 RPL Network Topology

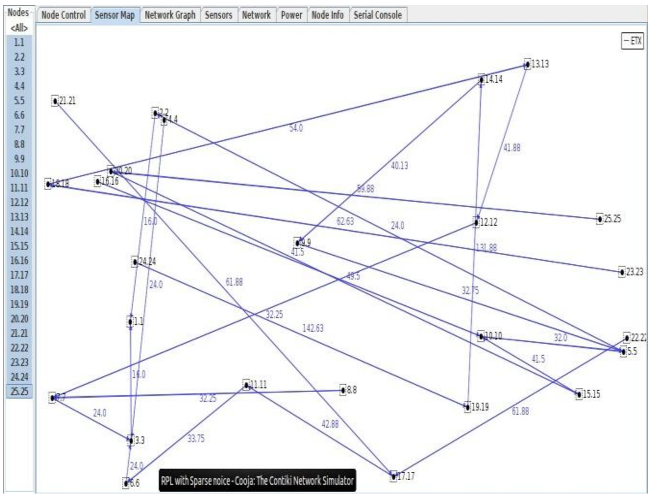

Figure 2 Topology of a WSN with 25 nodes.

II. Simulation Setup

We design a sample network in the Cooja simulator containing 24 client nodes and 1 sink node acting as root of the DODAG. The network scenario is shown in Figure 3. The server is using a sample application *udp-sink.c* while all other nodes are using *udp-sender.c*.

To introduce lossyness in wireless medium, we used the Cooja Unit Disk Graph Medium which introduces lossyness with respect to relative distances of nodes in the Radio Medium. The parameters for the Simulation and its environment are shown in Table 1.

As shown in Table 1 the start delay is the initial delay time for the application to start transmitting its messages to the sink node. This initial start time is the approximate time sufficient for the initial network convergence. This also ensures the packet delivery without data lost because of the lack of network connectivity. Therefore a correct evaluation can be performed on the number of packets sent.

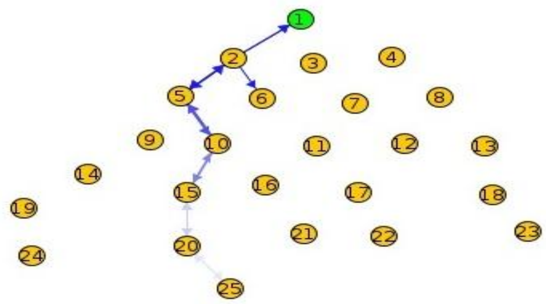

Figure 3 RPL DODAG generation, 1 sink node and 24 sender nodes

Parameters	Values
Start Delay	15 sec
Total Packets	686
RPL MOP	Upward and Downward Route
OF	OF0, ETX
DIO min	12
TX Ratio	100 %
RX Ratio	35 %

Table 1 Parameters and their Values used for Simulation Setup

III. Performance Metrics

(a) Convergence Time: The Convergence Time of the RPL DAG is defined as the amount of time needed by all the reachable nodes in the network to join the DAG. This convergence duration should be considered as the initial Convergence Time in a RPL network with static nodes [7].

Convergence Time = Last DIO joined DAG - First DIO sent ……………. (Eq.1)

(b) Packet Delivery Ratio: It is defined as the number of received packets at the sink to the number of sent packets to sink. We take the average PDR of all the packets received successfully at sink [7].

*Average PDR= (Total Packets Received / Total Packets Sent) * 100 …………. (Eq.2)*

(c) Transmit Power: It is defined as the power consumption on transmitting the radio signals. Here we will compute Average Transmitted Power.

Average Transmit Power = Total Transmit Power / Total No. of Nodes ………………………………………. (Eq.3)

(d) Listen Power: It is defined as the power consumption on reception process of radio signals at nodes. Here we will compute Average Listen Power.

Average Listen Power = Total Listen Power / Total No. of Nodes .... (Eq.4)

IV. Results

After running, the simulation on COOJA simulator and applying the above discussed performance metrics formulas. The results, we got are as follows:

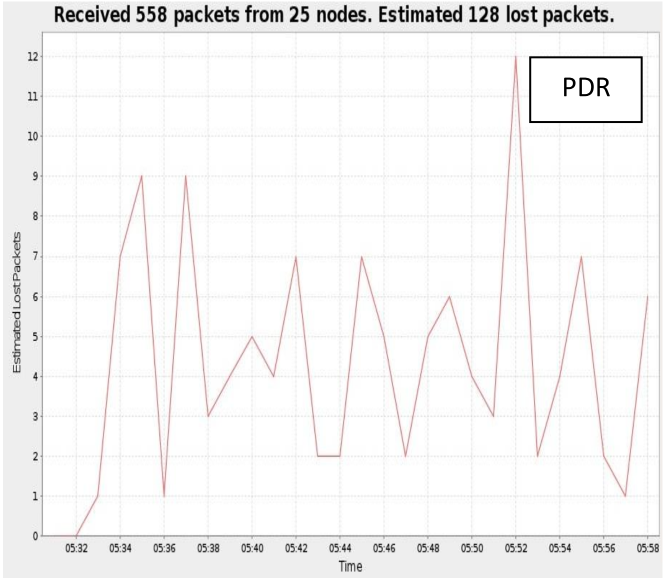

Figure 4 Packet Delivery Ratio

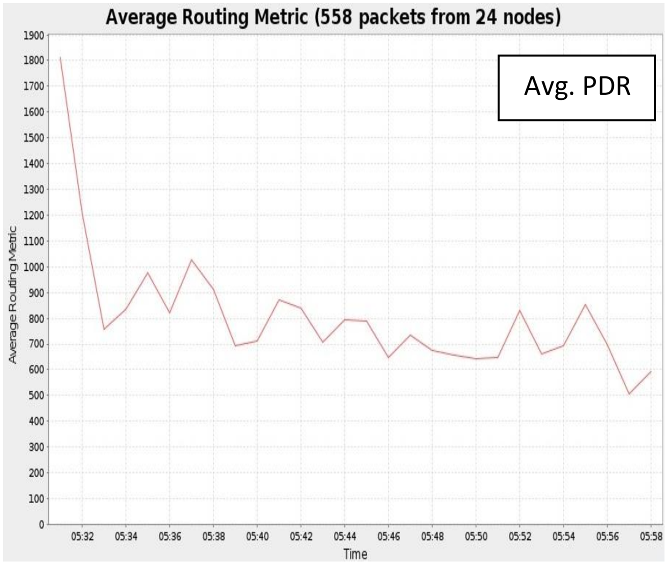

Figure 5 Average Routing Metric

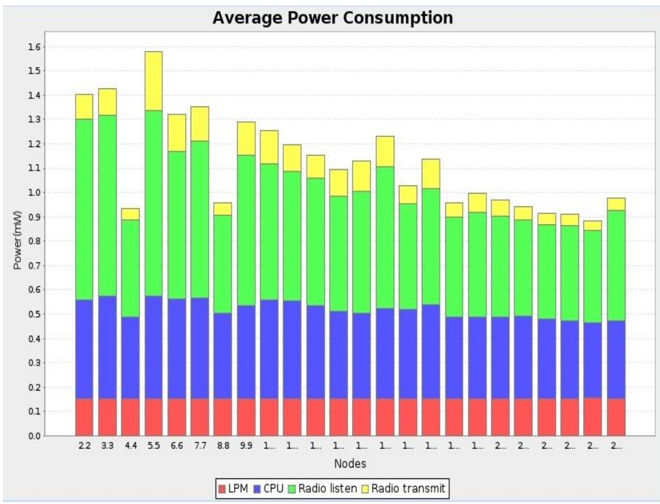

Figure 6 Average Power Consumption of all sender nodes.

Performance Metric	Results
Convergence Time	Approx.. 14 seconds
Packet Delivery Ratio (PDR)	81.34 %
Avg. CPU Power Consumption	0.367 mW
Avg. Transmit Power Consumption	0.098 mW
Avg. Listen Power Consumption	0.510 mW

Table 2 Results obtained from simulation.

V. Conclusion

As we run and studied this simulation in Sparse formation i.e. the number of links are less than the maximum nos. of links we can make. It is proposed to reduce the power consumption in Wireless Sensor Networks. but the convergence time for only 25 nodes is approximately 14 seconds which is much higher as compare to the convergence time for 80 node network and that was approx. 15-16 seconds with DIO minimum. So, we need to optimize the RPL by improving Objective Functions. PDR is need to be improve by optimizing this protocol.

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