The Comparison of RPL, ORPL, and LOADng for Low-power Biomimetic Robot Networks

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Abstract: There have been numerous routing protocols designed for multi-hop low-power networks. However, they usually suffer from outdated routing information when nodes have mobility. Even when a device duty-cycles for low energy consumption, excessive control overhead monopolizes the medium. In this work, we compare three state-of-the-arts, RPL, ORPL, and LOADng in a simulated biomimetic robot network, which requires both low energy consumption and mobility support. In order to evaluate the protocols in duty-cycled network with mobile robots, Cooja simulator is used. Through the extensive simulations on Cooja, we found RPL and ORPL does not maintain valid routes, while LOADng suffers from redundant broadcast packets.

Keywords: RPL, ORPL, LOADng, Mobility, Low-power, LLN, Biomimetic robot network

1. INTRODUCTION

Low-power and lossy networks (LLNs) have been studied and deployed in real life for various applications. In LLN applications, devices need to be energy-efficient due to battery-based operation. Thus a node usually duty-cycles, which means it is not always awake, but periodically checks the medium. If there is an ongoing transmission, the node receives the transmission. Otherwise, its radio is off. Transmission power is quite low in LLN nodes (e.g. less than 0dBm). It makes a LLN network usually form multi-hop topology. In order to enable multi-hop communication to be reliable, a lot of LLN routing protocols have been proposed. In this work, we compare three representative routing protocols in a LLN network using Cooja simulator.

2. BACKGROUND

In 2012, IETF working group standardized IPv6 routing protocol for LLNs, named as RPL [1]. It builds directed acyclic graphs (DAGs) based on routing metrics, such as expected transmission count (ETX) and the number of hops. In most LLN scenarios, RPL constructs tree-like routing topology called destination-oriented directed acyclic graph (DODAG) rooted an LLN gateway or a sink. Each RPL node selects the best parent based on the routing metric, and forwards data packets to the parent. This happens in all nodes in the network, thus the packets arrive at the sink at last.

Opportunistic RPL (ORPL) was firstly introduced in [2]. ORPL builds upon RPL, but its packet transmission is not unicast, but anycast, which means each data packet does not specify the next-hop receiver in MAC header. Instead, the routing cost of the sender is shown in the header. Any packet receiver could be the potential forwarder if it has a low routing cost to the sink. Thus, a receiver determines to whether to forward the packet immediately after packet reception. In ORPL, expected duty cycle (EDC) is used for the routing metric, reflecting the multi-path diversity. It represents the number of MAC wakeup periods required to reach the root. It is equivalent multipath ETX. If the number of neighbors is low, or link qualities with neighbors are poor, EDC increases.

However, RPL and ORPL were not designed for mobile LLNs, but just for static networks. Emerging IoT applications like hospital monitoring, industrial management, and biomimetic robot networks for military purpose require mobility in the network. The Lightweight On-demand Ad hoc Distance-vector Routing Protocol - Next Generation (LOADng) [3] derived from AODV [4] aims to support mobile IoT applications. Using Route Requests (RREQs), a LOADng node searches a route in on-demand manner. RREQ is flooded in the entire network until it reaches the destination. Meanwhile, the RREQ generator waits for a Route Request (RREP) from the destination. RREP is delivered to the RREQ generator through multi-hop unicast transmissions. If a node including the RREQ generator receives RREP, it makes or updates routing path towards the RREP source, which is the RREQ destination.

3. PERFORMANCE EVALUATION

3.1 Experimental setup

In this section, we use Cooja simulator for performance evaluation of RPL, ORPL, and LOADng. Cooja simulator works on Contiki which is the open source OS for IoT. We deployed total 20 nodes as shown in Fig. 1. There are three kinds of nodes. First, node 2 is the sink, while node 1 and 3-7 are data forwarders. They do not generate data packets. Each of the other nodes moves according to random waypoint model in the 90m x 90m squared network, and generates a packet every 30 seconds. Their maximum speed is 2m/s. The reason data forwarders exist is to provide mobile sources higher connectivity with the sink. Transmission power in the simulation is -10dBm whose maximum transmission range is about 10m.
3.2 Experimental results

We compared RPL (R), ORPL (O), and LOADng (L) with various duty-cycle rates from 32Hz to 2Hz. Fig. 2 shows end-to-end packet reception ratio (PRR) in the sink. Duty cycle shown Fig. 3 is the ratio of radio-on time, which represents energy consumption for radio communication. For example, L4 indicates LOADng with 4Hz duty-cycling where a node checks the medium every 250ms.

Firstly, the worst reliability performance (PRR) is shown in RPL. In mobility scenario, RPL suffers from excessive link losses due to outdated parent information. Its routing update cannot follow the rapid topology change. Whereas ORPL shows better PRR since it is more robust to network mobility thanks to multi-path diversity from anycast communication. However, its PRRs are less than 67% by outdated routing information. The best PRR performance is obtained with LOADng. Its on-demand route searching makes the routing state valid. It is notable PRRs of LOADng decrease when duty-cycle rate reduces. In LOADng, RREQ is broadcasted in the network. In order to broadcast a packet in the duty-cycled network, a sender must repeat the same packet transmissions during the channel check interval, since it does not have any knowledge of when neighbors wake up. Thus, long channel occupation time by RREQ transmissions makes the medium congested, leading to low PRR and high energy consumption (duty cycle). We conclude on-demand RREQ in LOADng is quite big burden in duty-cycled LLNs. Thus, we used L_NULL (LOADng without duty-cycling) as the upper bound of PRR. On the other hand, RPL and ORPL maintain about 2-3% duty-cycles.

4. CONCLUSION

In this paper, we reviewed RPL, ORPL, and LOADng. Then they are evaluated in a mobile LLN scenario using Cooja simulator with mobility plugin. We found LOADng outperforms RPL and ORPL with respect to network reliability. However, it suffers from unacceptable energy consumption for LLN. Especially duty-cycled network, LOADng shows both worst PRR and duty cycle. We conclude that a new routing protocol needs to be developed and proposed for the LLN with both mobility and duty-cycling operation, which is one of our future work.

REFERENCES


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