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Review Article

A Comparative Study of the Routing Protocols LOAD and RPL in Low-power and Lossy Networks (LLN)

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Abstract: Routing protocols for sensor networks are often designed with explicit assumptions, serving to simplify design and reduce the necessary energy, processing and communications requirements. IPv6 Routing Protocol for Low Power and Lossy Networks (RPL) is a routing protocol specifically designed for Low power and Lossy Networks (LLN) compliant with the 6LoWPAN protocol. It currently shows up as an RFC proposed by the IETF ROLL working group. However, RPL has gained a lot of maturity and is attracting increasing interest in the research community. As a point of comparison, a different protocol, called LOAD, is also studied. LOAD is derived from AODV and supports more general kinds of traffic flows.
Keywords: Routing protocols for Low power and Lossy Networks (LLN), AODV

INTRODUCTION

Sensor networks differ from more traditional networks" in that devices making up a sensor network has connectivity maintenance and data forwarding as auxiliary tasks to its data acquisition. Ignoring the applications, the network itself can be described by (i) the devices being many thousands in number, (ii) with very limited internal (memory, CPU), external (communications capacity) and energy resources, and that (ii) the communications channel between devices typically has unattractive characteristics: low-bandwidth, high loss rates and volatile links with limited persistency over time. The term Low-power Lossy Networks (LLN) is therefore commonly used for describing such networks [1-2].

Yet, despite these challenges, routing protocols are required for establishing and maintaining multi-hop connectivity in LLNs, for situations where it is unfeasible or impossible to provision a sensor network deployment such that all devices, necessitating communication between each other, are within direct connectivity. The Internet Engineering Task Force (IETF) has a long tradition of developing and standardizing routing protocols [3-4]. Initially, for fixed Internet infrastructures, where the conditions are more lenient than in LLNs: routers generally have abundance of computational capacity and few energy constraints, links are predominantly “good" with few losses and while Internet routing protocols such as OSPF are able to handle some network topology changes, these are generally rare, and generally occur only as a result of relatively catastrophic events: a cable being cut, for example. In the late 1990'es, the IETF started investigating MANETs Mobile Ad hoc Networks. Generally thought of as multi-hop wireless networks of mobile devices, a crop of routing protocols were developed and standardized, notably OLSR and AODV. Able to manage more dynamic topologies and the characteristics of wireless network interfaces, this work introduced a new dichotomy in routing protocol classification: OLSRv2 being a classic link state routing protocol, optimized for MANETs, it maintains paths to all destinations at all times, and this even before such paths are needed proactively. AODV approached the same problem in a different fashion, by discovering and maintaining paths to destinations only as needed by application traffic reactively. For both, however, the assumption was that while the network topology might be dynamic and the wireless connectivity volatile, the devices in the network still had a relative abundance of both computational power and energy.

RPL Overview

RPL the Routing Protocol for Low Power and Lossy Networks" (RPL) is a proposal for an IPv6 routing protocol for Low-power Lossy Networks (LLNs) by the ROLL Working Group in the Internet Engineering Task Force (IETF) [1-3]. This routing protocol is intended to be the IPv6 routing protocol for LLNs and sensor networks, applicable in all kinds of deployments and applications of LLNs. The unofficial goal, of the ROLL Working Group, is to prevent fragmentation in the sensor networking market by providing an IP-based routing standard, and solicit broad industrial support behind that standard. The objective of RPL and ROLL is to target networks which comprise up to thousands of nodes, where the majority of the nodes have very constrained resources, where the network to a large degree is "managed" by a (single or few) central 'super nodes", and where handling mobility is not an explicit design criteria. Supported traffic patterns include multipoint-to-point, point-to-multipoint and point-to-point traffic. The emphasis among these traffic patterns is to optimize for multipoint-to-point traffic, to reasonably support point-to-multipoint traffic and to provide basic features for point-to-point traffic, in that order.

RPL was developed from four sets of requirements that represent the four main foreseen uses of WSN: Home Automation, Building Automation, Industrial and Urban environments. The documents highlight many differences in the various environments, but on one point they're mostly agreeing: the main use of WSNs is foreseen to be data gathering or data distribution. As a consequence, RPL focuses on building very efficient routes between one or more 'root' nodes and all the other nodes in the network. RPL supports actively three kinds of traffic: Point to Point, Point to Multipoint and Multipoint to Point, with four Mode of Operations(MOP). The multiple MOPs are due to the WSNs peculiarities. Even in 802.15.4, two different kinds of nodes are defined: Full Functional Devices (FFD) and Reduced Functional Devices (RFD), in order to accommodate the fact that some nodes might have little or no computational power. Moreover some RPL nodes might have more stringent constraints, hence the different MOPs. The four MOPs are: 'No downward routes', Non Storing, Storing, Storing with Multicast support. The base concept in RPL is the Destination Oriented Directed Acyclic Graph (DODAG). Assuming that the biggest part of the node's communication are flowing to or from a root node (the gateway between the WSN and the Internet usually), it is pretty straightforward that building a DODAG having as the destination the root node is equivalent to solve the routing problem. The whole RPL protocol tries to build, maintain and optimize DODAGs. The base idea is simple; the solution is not so simple. A DODAG is 'built' by a root node, however in a network there might exist multiple root nodes. Moreover even a single root node could need to have multiple DODAGs due to (mainly) node's or traffic constraints. To make the problem more complex, the nodes might be moving, the links might be vanishing due to moving obstacles, etc. Hence, the protocol as a whole is very dynamic. On the other hand, ROLL group made an impressive work to maintain the protocol very simple yet extremely flexible. The base operation is: when a node is not connected to a DODAG it sends special messages named DODAG Information Solicitation (DIS) to a special IPv6 multicast group. Any other node already in a DODAG can send back a DODAG Information Object (DIO). The node will choose the more suitable node and will join its DODAG. The main remaining issues are: 1) how to prevent loops, 2) how to rebuild a broken DODAG, 3) how to optimize the DODAG, 4) how to discover the 'downward' routes.

LOAD Overview

LOAD is a protocol, derived from AODV and adapted for LLNs [5]. Thus, the basic operation of LOAD is identical to that of AODV: a device with a packet to deliver to a destination, and which does not have a valid entry in its routing table for that destination, will issue a route-request (RREQ) message, diffused through the network so as to reach all other devices. When a device forwards this route-request, it records an entry in its routing table towards the originator of that route-request a reverse route indicating the eventual path from the destination to the originator. If the destination is present in the network, it will eventually receive the route-request and will respond by a route-reply (RREP), unicast to the originator of the route-request along the previously installed reverse route. As that route-reply is being forwarded along this reverse route, the devices forwarding it will instill a forward route towards the destination. Once the route-reply arrives at the originator of the corresponding route-request, a bi-directional path is installed, available for use. When a link is detected to be broken (typically through a link-layer notification of a data-packet failing to be delivered to a next hop), the detecting router may engage in a route- repair operation essentially a new route-request/route-reply cycle to discover a path to the destination and if that fails, issue a route-error (RERR) message to inform the source of the failed data-packet of the error. While this route discovery is performed, any IP-packets to the destination are buffered in the source router. When a route is established, these packets are transmitted and if no route can be established, they are dropped.

The main differences between AODV and LOAD are

1. LOAD simplifies the protocol behavior by disallowing that intermediate devices respond with a route-reply even if they have an active route to the intended destination thereby eliminating the need for destination sequence numbers.
2. Where in AODV, in case a device detects a link breakage, that device will attempt to transmit the route-error message to all neighbors which have recently used it as a next-hop on a path to the destination of the undelivered package, LOAD disables that thereby eliminating the need to a device to maintain a precursor list.

Other, minor, differences include simplification of the packet format, support for compressed IPv6 addresses etc. LOAD does not impose any specific roles on any specific devices, notably has no controller or root with specific responsibilities for the network operation. Thus, the default traffic pattern supported by LOAD is bi-directional point-to-point traffic. The one sacrifice that LOAD makes with respect to data traffic, in simplifying from AODV, is that it assumes that a given destination typically is in communication with only a single source at a given time hence, the suppression of the precursor list.

Table-1: Parametric Comparison

Protocol	LOAD	RPL
Topology	Flat	Hierarchical, Flat
Type	On-Demand	Proactive
Algorithm	Distance Vector	Distance Vector Source Routing
Local Repair	Not Use	Use
Mobility	Static, Mobile	Static, Mobile
Scalability	High	High
Hello Messages	Not Use	Not Use
Memory Usage	Low	Low
Energy Usage	Low	Low
Supported Traffic	P2P	P2MP, MP2P, P2P

CONCLUSION

RPL and LOAD represent two different philosophies for routing protocols in LLNs. RPL is optimized for specific topologies and traffic patterns a central controller with specific responsibilities for topology formation and maintenance, and towards which the majority of traffic flows. Thus, the strength of RPL is proactive construction of a collection tree for forwarding such traffic. LOAD represents a perhaps less optimized protocol, however one wherein the philosophy is an entirely distributed mode of operation, where paths are discovered on demand and so as to be bi-directional.

Future work

In summary, RPL and LOAD are very promising routing protocol for LLNs as they provide a great level of flexibility to deal with different requirements of underlying applications. In this paper, we have surveyed the most important features of the RPL and LOAD routing protocols, with the aim to provide researchers with a quick yet comprehensive introduction of RPL and LOAD.

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