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# ROUTING PROTOCOL FOR LOW POWER AND LOSSY NETWORKS

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## ABSTRACT

The techniques presented herein provide Routing Protocol for Low power and Lossy Networks (RPL) that enhances the incorporation of RPL Unaware Leaves (RULs) into a network while also improving the flexibility of the network deployment. Specifically, the techniques presented herein create one or more proxies for RULs that can reduce the number of messages a RUL needs to receive. Thus, a RUL can wake less and preserve its battery. The one or more proxies proxy IPv6 protocol, such as DHCPv6, for the RUL and maintain the keep alive state for RUL.

## DETAILED DESCRIPTION

Smart ubiquitous networks for large-scale outdoor Internet of Things (IoT) communication, such as Wi-SUN, are now becoming quite popular. At least some of these networks leverage Routing Protocol for Low power and Lossy Networks (RPL) to establish a tree-based topology for a wireless mesh network (WMN, also generally referred to herein as “network” or the like). At least some of these networks are attempting to define the behavior of Limited Function Devices (LFD) that operate as leaf nodes and always work with battery. For example, Wi- SUN proposes to allow for RPL Unaware Leaves (RULs) in a RPL network based on the workflow illustrated in Figure 1 below.

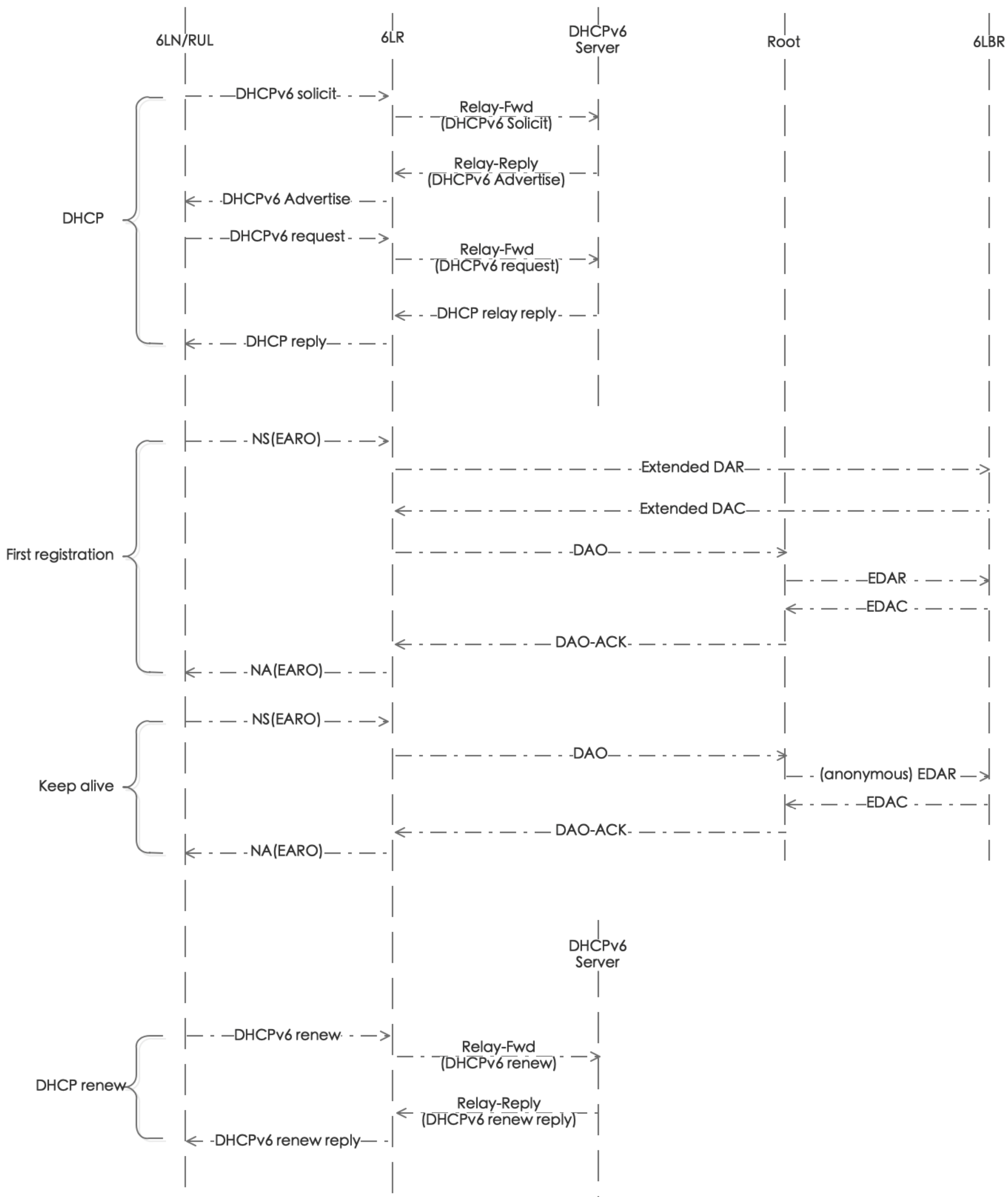


**Figure 1**

In this diagram, 6LN is representative of a LFD (e.g., a IPv6 over Low-Power Wireless Personal Area Networks (6LoWPAN) Node), 6LR is representative of a 6LoWPAN Router, and 6LBR is representative of a 6LoWPAN Border Router. Additionally, in the workflow, Dynamic Host Configuration Protocol (DHCP) is a perquisite to registration and the registration and keep alive flows involve: Neighbor

Solicitations with Extended Address Registration Option (NS(EARO)); Extended Duplicate Address Requests (EDARs); Extended Duplicate Address Confirmations (EDACs); Destination Advertisement Object (DAO); and Neighbor Advertisement with EARO (NA(EARO)).

Notably, over the course of this workflow, the LFD (e.g., 6LN/RUL) must be awake several times to collect enough response messages (DHCP and registration flows are one-time operations, but keep alive/DHCP renew flows occur periodically). However, waking for each message may drain the battery of the LFD and, since the LFD is a battery-powered node, it should sleep if it cannot get response message immediately. Additionally, in this workflow, the RUL (the LFD) needs to support an IPv6 stack, but if the RUL is a low power wider area network (LPWAN) node that does not know its address, binding DHCPv6 to the RUL may not work.

In view of the foregoing, the techniques presented herein enhance LFD/RUL handling in in a RPL network by providing a LFD/RUL proxy. Specifically, in a first embodiment the techniques provided herein use a router (e.g., 6LR) to proxy IPv6 protocol for the LFD/RUL and maintain the keep alive state for LFD/RUL, as shown in Figure 2:

For clarity, Figure 2 depicts the techniques presented herein with the same devices and workflow depicted in Figure 1. However, the techniques could also be applied across a wide variety of LFDs/RULs, including any LPWAN node. That said, when a router (e.g., 6LR) acts as an IPv6 protocol proxy for a RUL, the router can complete the first registration and keep alive mechanism for the RUL/LFD. Then, the first registration flow is simplified to two message between RUL/LFD and the router (e.g., 6LR) so that the RUL/LFD only has to wake twice. In at least some embodiments, the router (e.g., 6LR) can act as the proxy for the RUL/LFD by leveraging Registration Ownership Verifier (ROVR). Regardless, after completing a registration, the proxy router can remove DHCP code to save memory (e.g., read-only memory (ROM) and/or random-access memory (RAM)).

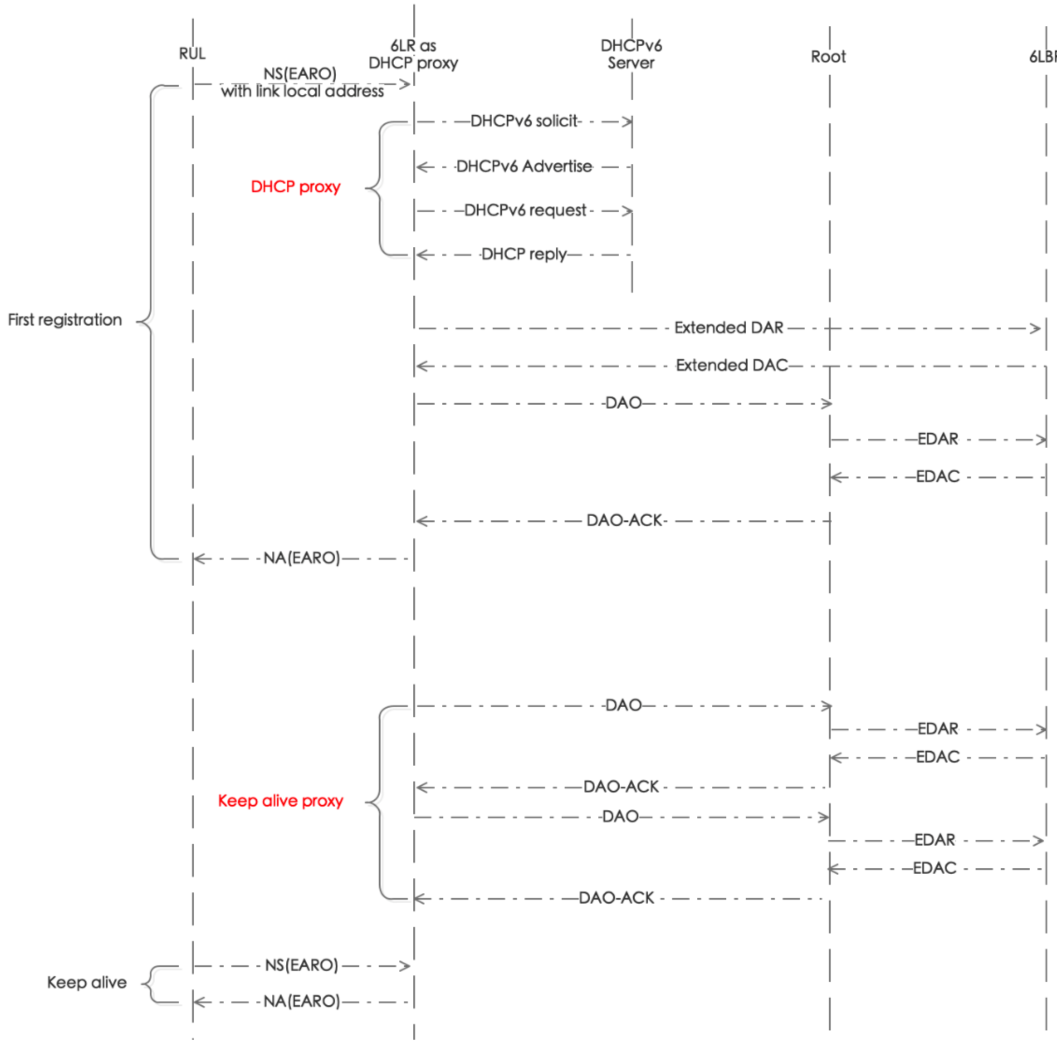


**Figure 2**

Additionally, the proxy router (e.g., 6LR) can maintain the keep alive state and DHCP state for the RUL/LFD so that the RUL/LFD can get a keep alive response immediately after sending a keep alive request. Thus, the RUL/LFD can wake less and sleep more, preserving its battery. Moreover, the keep alive interval between the router (e.g. 6LR) and a root node (e.g., a gateway) can be different from the keep alive interval between the RUL/LFD and its proxy router. This provides more flexibility for inter-operation with current root node.

In addition to or as an alternative to using a router (e.g., 6LR) as the RUL/LFD proxy, a border router (e.g., 6LBR) can act as a proxy for the RUL/LFD, as shown in Figure 3:

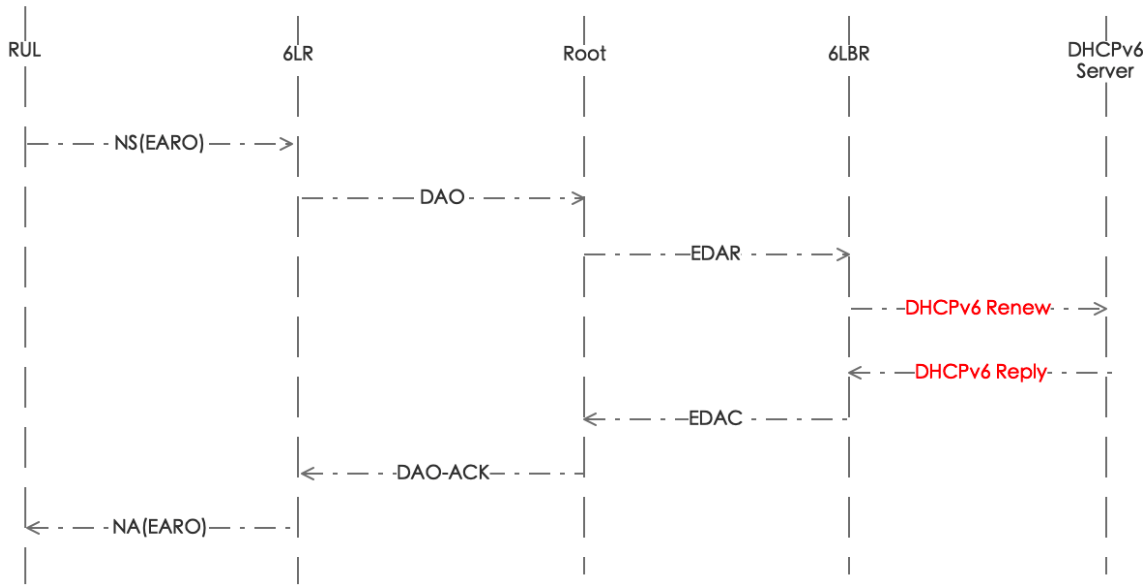


**Figure 3**

For clarity, Figure 3 also depicts the techniques presented herein with the same devices and workflow depicted in Figure 1. However, again, the techniques shown in Figure 3 could also be applied across a wide variety of LFDs/RULs, including any LPWAN node. The border router (e.g., 6LBR) can proxy DHCPv6 renew for all RUL because EDAR carrying a DHCPv6 Unique Identifier (DUID) is sent to 6LBR. Thus, the border router can avoid the original DHCPv6 renew which are going through the Low power and Lossy Network.

Advantageously, the techniques presented may preserve battery for a wide variety of RULs/LFDs. The techniques may enable a wide variety of LFDs/RULs to join an IoT network. For example, even if a RUL is a LPWAN node that typically uses short/compressed addresses for communication and cannot support full IPv6 stack (e.g., the node is not a 6LoWPAN node), using a proxy for IPv6 stack may allow the node to join a RPL network. Moreover, if an IoT network needs to support 6LoWPAN and LPWAN nodes at the same time, the techniques presented herein can use one root node for both types of nodes (while currently deployments may require two root node gateways, one for 6LoWPAN and one for LPWAN). Thus, the techniques presented herein not only enhance RUL incorporation into a network, but also make the network more flexible.

In summary, the techniques described herein provide Routing Protocol for Low power and Lossy Networks (RPL) that enhances the incorporation of RPL Unaware Leaves (RULs) into a network while also improving the flexibility of the network deployment. Specifically, the techniques presented herein create one or more proxies for RULs that can reduce the number of messages a RUL needs to receive. Thus, a RUL can wake less and preserve its battery. The one or more proxies proxy IPv6 protocol, such as DHCPv6, for the RUL and maintain the keep alive state for RUL.