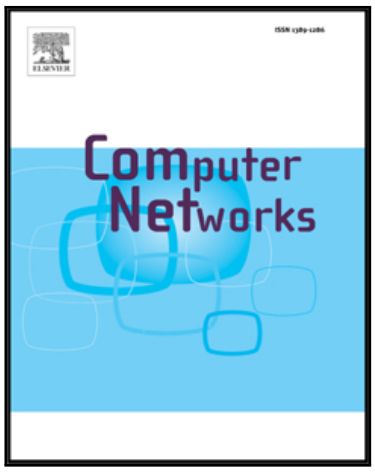

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Matrix: Multihop Address allocation and dynamic any-To-any Routing for 6LoWPAN

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Abstract

Standard routing protocols for IPv6 over Low power Wireless Personal Area Networks (6LoWPAN) are mainly designed for data collection applications and work by establishing a tree-based network topology, enables packets to be sent upwards, from the leaves to the root, adapting to dynamics of low-power communication links. In this work, we propose Matrix, a platform-independent routing protocol that utilizes the existing tree structure of the network to enable reliable and efficient any-to-any data traffic in 6LoWPAN. Matrix uses hierarchical IPv6 address assignment to optimize routing table size while preserving bidirectional routing. Moreover, it uses a local broadcast mechanism to forward messages to the right subtree when a persistent node or link failures occur. We implemented Matrix on TinyOS and evaluated its performance both analytically and through simulations on TOSSIM. Our results showed that the proposed protocol is superior to available protocols for 6LoWPAN when it comes to any-to-any data communication, concerning reliability, message efficiency, and memory footprint.

Keywords: 6LoWPAN, IPv6, CTP, RPL, any-to-any routing, fault tolerance

1. Introduction

IPv6 over Low-power Wireless Personal Area Networks (6LoWPAN[1]) is a working group inspired by the idea that even the smallest low-power devices should be able to run the Internet Protocol to become part of the Internet of Things. The main function of a low-power wireless network is usually some sort of data collection. Applications based on data collection are plentiful, examples include environment monitoring [1], field surveillance [2], and scientific observation [3]. In order to perform data collection, a cycle-free graph structure is typically maintained and a convergecast is implemented on this network topology. Many operating systems for sensor nodes (e.g. Tiny OS [4] and Contiki OS [5]) implement mechanisms (e.g. Collection Tree Protocol (CTP) [6] or the IPv6 Routing Protocol for Low-Power and Lossy Networks (RPL) [7]) to maintain cycle-free network topologies to support data-collection applications.

In some situations, however, data flow in the opposite direction — from the root, or the border router, towards the leaves becomes necessary. These situations might arise in network configuration routines, specific data queries, or applications that require reliable data transmissions with acknowledgments. Standard routing protocols for low-power wireless networks, such as CTP (Collection Tree Protocol [6]) and RPL (IPv6 Routing Protocol for Low-Power and Lossy Networks [7]), have two distinctive characteristics: communication devices use unstructured IPv6 addresses that do not reflect the topology of the network (typically derived from their MAC addresses), and routing lacks support for any-to-any communication since it is based on distributed collection tree structures focused on bottom-up data flows (from the leaves to the root).

The specification of RPL defines two modes of operation for top-down data flows: the non-storing mode, which uses source routing, and the storing mode, in which each node maintains a routing table for all possible destinations. This requires $O(n)$ space (where n is the total number of nodes), which is unfeasible for memory-constrained devices. Our experiments show that in random topologies with one hundred nodes, with no link or node failures, RPL succeeds to deliver less than 20% of top-down messages sent by the root (see Figure 8).

Some works have addressed this problem from different perspectives [8, 9, 10]. CBFR [8] is a routing scheme that builds upon collection protocols to enable point-to-point communication. Each node in the collection tree stores the addresses of its direct and indirect child nodes using Bloom filters to save memory space. ORPL [9] also uses bloom filters and brings opportunistic routing to RPL to decrease control traffic overload. Both protocols suffer from false positives problem, which arises from the use of Bloom filters. Even though CTP does not support any-to-any traffic, XCTP [10], an extension of this protocol, uses opportunistic and reverse-path routing to enable bidirectional communication in CTP. XCTP is efficient in terms of message overload, but exhibits the problem of high memory footprint.

In this work, we build upon the idea of using hierarchical

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[1]We use the acronym 6LoWPAN to refer to Low power Wireless Personal Area Networks that use IPv6