VRIJE UNIVERSITEIT BRUSSEL

The faculty of Engineering of the Vrije Universiteit Brussel invites you to attend the public defense leading to the degree of

DOCTOR OF ENGINEERING SCIENCES

of **Eden Teshome Hunde**

The public defense will take place on **Friday 15th November 2024 at 10am** in room **D.2.01** (Building D, VUB Main Campus)

To join the digital defense, please click here

Meeting ID: 395 695 808 639
Passcode: wBMhrd

CROSS-LAYER DESIGN, IMPLEMENTATION AND EVALUATION OF IPV6 MULTICAST FOR RADIO DUTY CYCLED WIRELESS SENSOR AND ACTUATOR NETWORKS

BOARD OF EXAMINERS

Prof. Dr. Ir. Leo Van Biesen

Prof. Dr. Ir. Wendy Meulebroeck

Prof. Dr. Ir. Jacques Tiberghien

Dr. Ir. Ing. Steffen Thielemans

Prof. Dr. Ir. Jean-François Determe

Prof. Dr. Bruno Quoitin

PROMOTORS

Prof. Dr. Ir. Kris Steenhaut

Prof. Dr. An Braeken

Prof. Dr. Ing. Towfik Jemal Ali

Prof. Dr. Kinde Anlay Fante

VRIJE UNIVERSITEIT BRUSSEL

Abstract of the PhD research

Wireless sensor and actuator networks (WSANs), consist of small-sized constrained sensing and/or actuating devices which can run an Internet Protocol version 6 (IPv6) network stack. In such WSANs, there is often the need for sending the same message to several devices in the WSAN, such as for applications for controlling all the lights in a building or turning on/off all the air conditioners in the room etc. For doing so, IP multicast can be an efficient solution.

In this work, we study Bidirectional Multicast RPL Forwarding (BMRF) as this protocol relies on forwarding tables put in place by the well-known Routing Protocol for Low Power and Lossy Networks (RPL) and allows to combine the best ideas of existing multicast protocols. Through RPL, a routing tree towards the sink is installed for multihop routing from node to sink, and the nodes' forwarding tables will also contain entries for reaching destinations in downward direction.

For downward forwarding IPv6 multicast packets, two methods exist. One is via link layer (LL), broadcasting a frame containing the IPv6 multicast packet. The other is to send several LL unicast frames containing that packet. BMRF allows a node to choose between these two methods. The best option will depend on the presence of a radio duty cycling (RDC) protocol. RDC is part of the medium access control (MAC) layer and puts the radio to sleep when no communication is needed. We investigate the influence of MAC/RDC protocols on BMRF's performance.

We evaluate the performance of BMRF on non-synchronized WSANs that use Carrier Sense Multiple Access (CSMA) as MAC and ContikiMAC as RDC. We demonstrate that LL unicast outperforms LL broadcast in terms of packet delivery ratio (PDR), delay, and energy consumption in many settings.

We investigate the performance of BMRF on WSANs with synchronous MAC and RDC based on Time Slotted Channel hopping (TSCH). This is more challenging, as TSCH needs a schedule to tell which action must happen in each timeslot. The actions can be to send or to listen on a given channel or to be idle. Idleness allows the radio to switch OFF, providing RDC. The schedule is not part of the standard and must be proposed by the system designer. An elegant autonomous scheduling method called Orchestra is available to accommodate traffic in a RPL tree. We extend Orchestra with a novel scheduling rule for supporting LL downwards forwarding through LL broadcast. Comparing LL unicast with LL broadcast forwarding teaches us that LL unicast outperforms LL broadcast in terms of packet delivery ratio (PDR), but the latter can be beneficial to certain applications, especially those sensitive to delay.

Before conducting the two previous evaluation studies, we investigate the performance of simple convergecast traffic while considering ContikiMAC and TSCH with Orchestra under RPL on the real dual Zolertia Firefly Motes (one is observed and other one is observing mote). This study served two purposes; it reminds the reader of the characteristics of those protocols and allowed to fine-tune the dual motes.

We also contributed by adapting the Orchestra to bursty convergecast traffic. Simulation results demonstrate that the new scheduler slightly improves PDR and reduces delay compared to state-of-the-art solutions.