ERCIM "ALAIN BENSOUSSAN" FELLOWSHIP PROGRAMME

ERCIM
European Research Consortium for Informatics and Mathematics

Scientific Report

First name / Family name	Martina Brachmann
Nationality	German
Name of the *Host Organisation*	RISE Research Institutes of Sweden
First Name / family name of the *Scientific Coordinator*	Thiemo Voigt
Period of the fellowship	01/02/2019 to 01/01/2020

I – SCIENTIFIC ACTIVITY DURING YOUR FELLOWSHIP

The main research activities followed during my ERCIM Fellowship are summarized here:

Reliable and Energy Efficient Data Transmission for Low-Power Wireless Networks

Many application scenarios for low-power wireless networks require the reliable and fast exchange of small data values. Examples include the dissemination of parameters – e.g., the set-point of a valve – in industrial control systems or smart buildings. In these settings, the communication is either periodic or event-driven. Synchronous transmission-based flooding can be used to reliably and quickly share data periodically in a low-power wireless network. Several approaches extend synchronous transmission-based flooding to event-driven systems by periodically sampling the network for potential events.

For nodes to be able to timely detect the presence of communication in form of data packets, they must regularly switch their radios on and check the channel for incoming transmissions. The more often this channel check is performed, and the longer each check lasts, the higher is the energy consumption of the nodes. Thus, channel sampling induces a high energy overhead in event-based traffic. However,

these frequent channel checks are needed to ensure a timely packet delivery. We address this trade-off with Whisper [2]. Whisper floods small amounts of data into a multi-hop network. In contrast to other approaches exploiting synchronous transmissions such as Glossy, Whisper does not let the nodes switch the radio from receive to transmit mode between messages. Instead, it makes nodes continuously transmit identical copies of a message and eliminates the gaps between subsequent transmissions. To this end, Whisper embeds the message to be flooded into a *signaling packet* that is composed of multiple *packlets* – where a packlet is a portion of the message payload that mimics the structure of an actual packet. A node must intercept only one of the packlets to detect that there is an ongoing transmission and that it should start forwarding the message. This allows Whisper to speed up the propagation of the flood and, thus to reduce the overall radio-on time of the nodes.

Time-Slotted Channel Hopping (TSCH)

In 2012, Time-slotted Channel Hopping (TSCH) was introduced as an amendment to the MAC layer of IEEE 802.15.4-2011. TSCH has been designed and standardized by the eponymous IETF working group with the goal to achieve low-power operation and high reliability in the data exchange in low-power wireless networks. TSCH was derived from WirelessHART and ISA 100.11a and applies TDMA and channel hopping. Despite being introduced in 2012, there are still open challenges. For example, TSCH has been designed for the 2.4 GHz frequency band. However, the IEEE 802.15.4 standard also defines the operation at sub-GHz frequencies at the physical layer. Until recently, this has not been considered in the design of TSCH.

We address the support of TSCH on multiple frequency bands within a single TSCH network in publication [1]. It allows to simultaneously run applications with different requirements on link characteristics and to increase resilience against interference. To this end, we first enable sub-GHz communication in TSCH, which has been primarily defined for the 2.4 GHz band. Thereafter, we propose two designs to support multiple physical layers in TSCH on the same nodes.

Smart Implicit Interactions

This project is built around developing a new interface paradigm for IoT called “smart implicit interaction”. Implicit interactions stay in the background thriving on data analysis of speech, movements and other contextual data, avoiding unnecessarily disturbing us or grabbing our attention. This project is a collaborated work between researchers from RISE Research Institutes of Sweden, Stockholm University and KTH Royal Institute of Technology.

During the project the participating researchers have created a range of applications for home, body, outdoors and intimate healthcare. They have also worked with autonomous systems: created the Tama robot that wakes up through eye-gaze interaction; and put custom-built drones on stage in an opera performance. Based on these explorations, they have put together a Soma Design toolkit, enabling early idea formations for these settings. The toolkit integrates heat, vibration, gaze interaction, shape-changing materials, biosensor input.

To support researchers exploring different designs with the Soma Design toolkit, we developed a so-called “Smart Implicit Hub”. The “Smart Implicit Hub” is the central heart that orchestrates all implicit interaction-based devices. It provides several

services in a single system such as sensor and actuator discovery, allocation, the orchestration of sensor inputs to corresponding actions of actuators and it also facilitates the integration of external sensors and actuators (e.g., smart phones).

II – PUBLICATION(S) DURING YOUR FELLOWSHIP

[1] M. Brachmann, S. Duquennoy, N. Tsiftes, and T. Voigt. IEEE 802.15.4 TSCH in Sub-GHz: Design Considerations and Multi-band Support. In: IEEE Conference on Local Computer Networks (LCN), 2019.

Abstract: In this paper, we address the support of Time-Slotted Channel Hopping (TSCH) on multiple frequency bands within a single TSCH network. This allows to simultaneously run applications with different requirements on link characteristics and to increase resilience against interference. To this end, we first enable sub-GHz communication in TSCH, which has been primarily defined for the 2.4 GHz band. Thereafter, we propose two designs to support multiple physical layers in TSCH on the same nodes. Our experimental evaluation shows that TSCH is applicable in a wide range of data rates between 1.2 kbps and 1000 kbps. We find that data rates of 50 kbps and below have a long communication range and a nearly perfect link symmetry, but also have a 20x higher channel utilization compared to higher data rates, increasing the risk of collisions. Using these findings, we show the advantages of the multi-band support on the example of synchronization accuracy when exchanging TSCH beacons with a low data rate and application data at a high data rate.

[2] M. Brachmann, O. Landsiedel, D. Göhringer, and S. Santini. Whisper: Fast Flooding for Low-Power Wireless Networks. In: ACM Transactions on Sensor Networks (TOSN), 2019

Abstract: This article presents Whisper, a fast and reliable protocol to flood small amounts of data into a multi-hop network. Whisper makes use of synchronous transmissions, a technique first introduced by the Glossy flooding protocol. In contrast to Glossy, Whisper does not let the radio switch from receive to transmit mode between messages. Instead, it makes nodes continuously transmit identical copies of the message and eliminates the gaps between subsequent transmissions. To this end, Whisper embeds the message to be flooded into a signaling packet that is composed of multiple packlets—where a packlet is a portion of the message payload that mimics the structure of an actual packet. A node must intercept only one of the packlets to detect that there is an ongoing transmission and that it should start forwarding the message. This allows Whisper to speed up the propagation of the flood and, thus, to reduce the overall radio-on time of the nodes. Our evaluation on the FlockLab testbed shows that Whisper achieves comparable reliability but 2× lower radio-on time than Glossy. We further show that by embedding Whisper in an existing data collection application, we can more than double the lifetime of the network.

III – ATTENDED SEMINARS, WORKHOPS, CONFERENCES

Project meeting: Smart Implicit Interactions – on April 10th, 2019 in Stockholm, Sweden
Seminar: RISE and Ericsson Security Day – on October 2nd, 2019 in Stockholm, Sweden
Conference: IEEE Conference on Local Computer Networks (LCN) – on October 14th till 17th, 2019 in Osnabruck, Germany
Project meeting: Smart Implicit Interactions – on December 9th till 10th, 2019 in Stockholm, Sweden

IV – RESEARCH EXCHANGE PROGRAMME (REP)

Duration: 1 week
Research Group: Inria EVA team, France
Scientific Contact: Thomas Watteyne
Description: The nature of work included:

- Giving a talk about current research in the Networked Embedded Systems group at RISE with a detailed discussion on our work for multiple physical layers for Time Slotted Channel Hopping (TSCH).
- Technical discussions with the group members on the research activities at the Inria group and possible future collaborations.