Faculty Exchange Program
Activity Report

I. Personal Information:

Applicant:	
Name:	**Nuno Pereira**
Position:	**Professor Adjunto**
Institution:	**School of Engineering, Polytechnic Institute of Porto**
Address:	**Rua Dr. António Bernardino de Almeida, 431**

II. Period of Visit:

From: 15-03-2017	**To:** 15-07-2017

III. Hosting department:

Host	
Name:	Anthony Rowe
Position:	Associate Professor

IV. Activity Report:

It was a privilege to collaborate closely with Professor Rowe's Wireless, Sensing and Embedded Systems (WiSe) Lab at CMU. From the start, I was integrated in the team taking part of several regular group meetings and particularly meetings dedicated to work on low power long range communication (LPWAN). This allowed me to have a good insight into several threads of ongoing work.

I highlight the following activities carried out:

1) performing tight time synchronization between smartphones and localization beacons using Bluetooth Low Energy BLE;

2) help in organizational tasks and attendance of CPSWeek 2017 and

3) performing research on LPWAN protocols and building up future collaborations related to this research.

I also highlight the following concrete outputs:

a) Submission of a conference paper including the results of the research on BLE synchronization;

b) Submission of a project proposal to support and enlarge collaborations on LPWAN protocols;

c) Contributions to the OpenChirp initiative.

During my stay, I also had the opportunity to follow the Embedded Systems Design Capstone (18-549) course. It was particularly interesting to see the public demonstrations of the projects developed during the course. The highlighted activities are described in more detail next.

BLE Synchronization for Indoor Localization

Professor Rowe's group has been working for some time on indoor localization, having already a mature platform that provides indoor localization for smartphones using ultrasonic signals

sent from localization beacons [1]. This line of work is now focusing on easier installation and lower beacon densities, which is essential when installing nodes as it is both expensive and time consuming, especially if they require wired power.

Most previous approaches to acoustic localization needed to perform time-difference-of-arrival to synchronize device clocks and this requires at least three visible beacons at the time of synchronization, which means additional node density. In order to reduce node density, smartphones should be able to compute the distance to a single localization beacon using time-of-flight. In this work, we looked at directly using BLE packet arrival timing to perform tight synchronization between an application running on a smartphone and beacons. We believe we are the first to show sub-millisecond synchronization with common smartphones and not requiring elevated privileges on the smartphone (i.e. requiring jail breaking or rooting the phone). Such sub-millisecond synchronization enables indoor localization to a single location beacon, increasing significantly the applicability of the current system in real-world scenarios.

[1] Patrick Lazik, Niranjini Rajagopal, Bruno Sinopoli, and Anthony Rowe. Ultrasonic Time Synchronization and Ranging on Smartphones. In Proceedings of the 21st IEEE Real-Time and Embedded Technology and Applications Symposium (RTAS 2015).

CPS Week 2017

I arrived when the final preparation of the Cyber-Physical Systems (CPS) Week (of which Professor Rowe was local arrangements co-Chair) was taking place. All the hard arrangements/decisions were done at the time, but I got the opportunity to get involved and support the effort that was preparing to receive about 800 researchers for a very active week-long program. This was also a great experience, and I enjoyed the opportunity to take part of this and to meet with all the colleagues coming for CPS Week. It was a great time to be at CMU and Pittsburgh.

Research on LPWAN

While Low-Power Wide-Area Network (LPWAN) technologies, such as Long Range (LoRa) are already being rolled out, there is still insufficient knowledge about its performance and how to tune available parameters such as spreading factors, transmission power or frequency sets. Notably, it is not well defined how LoRa networks will be managed as the number independent LPWANs grows. The stay at CMU was key to delineate a long-term research effort where our main goal is to investigate low-overhead collaborative network-management solutions such that the communication channels are used efficiently. The idea is to develop models that allow studying and predicting the performance of LPWAN protocols under realistic conditions and use these models to build a collaborative management solution for LPWANs.

This research aims to leverage and broaden the collaboration with WiSe Lab, currently developing OpenChirp (http://openchirp.andrew.cmu.edu/), a pioneer infrastructure for sensing data collection and processing, and as has several research prototypes gateways and end-devices based using LoRa. During my stay at CMU, I made contributions to parts of the software infrastructure of Openchirp, publicly available at https://github.com/OpenChirp. This work enabled me to gather significant knowledge about the technology and insights into what are the concrete emerging research problems.

Acknowledgment

I cannot say enough about the way I was received by Professor Anthony Rowe. I was very fortunate to work with a remarkable researcher, leader and educator that treated me not only as a peer but also as an old friend. Thank you! I would like to express my deep gratitude to each and every one of the WiSe Lab team: Adwait, Artur, Craig, Khushboo, Max, Niranjini, Oliver, Patrick, Toni, all the new students. You were fantastic hosts and were always available to help

out wherever and whenever needed for these past few months.

My special thanks to all the team at CyLab that does great work to support us. My sincere appreciation to the large community of staff, faculty and students I had the opportunity to meet during this time. The seminars, workshops, happy hours, board games nights, and other organized activities provided me great moments of personal and professional development.

My time at CMU would not be possible without the CMU Portugal Program, and I would like to start by thanking FCT for supporting this program that provides Portuguese students and Faculty great opportunities to study and perform research in this world-class environment. Thank you to the CMU Portugal directors, professors José Moura and João Claro, and all the staff that supported me: Sara Brandão, Lori Spears, Ana Moura, Ana Lopes, Vera Pinto, Christina Danner. I appreciate all your help and support.

Finally, a thank you to my department and home Institution for allowing me to engage in this program.