Scientific Report

First name / Family name	Maddalena Nurchis
Nationality	Italian
Name of the *Host Organisation*	VTT Technical Research Center of Finland
First Name / family name of the *Scientific Coordinator*	Jouni Hiltunen
Period of the fellowship	01/10/2013 to 31/12/2014

I – SCIENTIFIC ACTIVITY DURING YOUR FELLOWSHIP

During the ERCIM fellowship I was part of the "network resource management and control" team.
The research activity was mainly related to the European research project SEAM4US, aimed at optimal energy management of underground transportation systems for energy savings. A wireless sensor network has been installed in the historic metro station of Passeig de Gracia in Barcelona, Spain, in order to collect environmental information and optimize the energy consumption according to the actual environmental conditions.
The main contribution of the team was the design, implementation and installation of the sensor network for environmental monitoring, as well as testing and evaluation of the system. Based on the status of the project at the time of my arrival, my personal contribution has been mainly focused on routing design and analysis of the collected data, especially in terms of network performance and reliability, leading to one publication [2] and two ongoing works [3,4] that are going to be submitted early this year. In addition, we are currently working on the design, implementation and performance evaluation of an adaptive duty cycle mechanism in order to improve the network performance in terms of sensor battery lifetime [5].
Finally, in collaboration with my previous team, I worked on data delivery in vehicular sensor networks, leading to the publication of paper [1].

II – PUBLICATION(S) DURING YOUR FELLOWSHIP

[1] R. Bruno and M. Nurchis, “Efficient Data Collection in Multimedia Vehicular Sensing Platforms”, Pervasive and Mobile Computing Journal (PMC), available online 22 May 2014, DOI 10.1016/j.pmcj.2014.05.003
Abstract - Vehicles provide an ideal platform for urban sensing applications, as they can be equipped with all kinds of sensing devices that can continuously monitor the environment around the travelling vehicle. In this work we are particularly concerned with the use of vehicles as building blocks of a multimedia mobile sensor system able to capture camera snapshots of the streets to support traffic monitoring and urban surveillance tasks. However, cameras are high data-rate sensors while wireless infrastructures used for vehicular communications may face performance constraints. Thus, data redundancy mitigation is of paramount importance in such systems. To address this issue in this paper we exploit sub-modular optimisation techniques to design efficient and robust data collection schemes for multimedia vehicular sensor networks. We also explore an alternative approach for data collection that operates on longer time scales and relies only on localised decisions rather than centralised computations. We use network simulations with realistic vehicular mobility patterns to verify the performance gains of our proposed schemes compared to a baseline solution that ignores data redundancy. Simulation results show that our data collection techniques can ensure a more accurate coverage of the road network while significantly reducing the amount of transferred data.

[2] J. Hiltunen, M. Valta, A. Ylisaukko-oja and M. Nurchis, “Design, Implementation and Experimental Results of a Wireless Sensor Network for Underground Metro Station”,

International Journal of Computer Science and Communication Networks, vol. 4, no. 3, pp. 58 – 66, July 2014
Abstract - Wireless sensor networks provide a prominent approach for environmental monitoring system in many different scenarios. Typically, sensors communicate through a mesh network architecture, in which each device functions also as a relay for other devices. The usage of multi-hop wireless paths raises the challenge of achieving robust communication and low energy consumption while optimizing the system maintenance costs due to battery replacements and network management. In this paper, we present the design and implementation of a wireless monitoring system deployed in an underground metro station, developed as a flexible cross-layer solution able to integrate time synchronization, duty-cycling and lightweight routing mechanisms. We provide detailed description of the system together with experimental results on the achievable energy efficiency improvement and on the adaptability of the routing protocol to the dynamicity observed in the station environment, providing relevant insights into properties and challenges of real WSN deployments.

[3] Maddalena Nurchis, Mikko Valta, Massimo Vaccarini, Alessandro Carbonari, "A wireless system for real-time environmental and energy monitoring of a metro station: lessons learnt from a three-year research project", to be submitted
Abstract - Optimal energy management of underground transportation systems is widely recognized as a key aspect for significant energy savings at regional level. The three-year long EU funded “Seam4us” research project (2011 to 2014) aims to create a system for optimized integrated energy management, relying on the Passeig de Gracia metro station in Barcelona as the pilot station. One of the outcomes of the project was the installation of a wireless sensor network, in order to track in real time both environmental and energy parameters. The data collected by the network have been exploited to inform an intelligent control system about the state of the station. In fact, a reliable real-time sensing is critical for implementing advanced control policies in any kind of environment. For that reason, this paper will report on the Seam4us findings regarding real-time sensing of that quite harsh domain.
First, a detailed description of the network will be provided, which includes the number, positions and types of sensors (e.g. temperature, air speed, pressure, CO2, PM10 etc...). The design criteria and constraints that led to the final installation will be argued. For example, not all the nodes of the network could be wired to the electric power, so most of them were bound to be battery powered. Then, post-processing functions, i.e. those algorithms turning raw data into the variables which can be processed by the controller, will be described. Also, the reason why those variables were relevant to environmental and energy tracking needs will be given. Finally, the general performance of the system will be discussed, in terms of reliability of data exchange and energy efficiency.

[4] Maddalena Nurchis, Mikko Valta, Jouni Hiltunen, “Wireless Sensor Network for underground metro station monitoring: a case study”, to be submitted
Abstract - Wireless Sensor Networks are nowadays considered a powerful solution for environmental monitoring in many different environments. Monitoring in underground transportation system has many important application scenarios, ranging from safety to energy savings. The SEAM4US project aims to reduce the energy consumption of underground transportation systems by relying on a wireless sensor network for environmental monitoring and a control system for the station subsystems, such as ventilation and illumination. The pilot station is the historic Passeig de Gracia metro

station in Barcelona, Spain, where a wireless sensor network has been deployed. In this paper, we report the most relevant findings from the testing and evaluation phase of the sensor networks, discussing in particular data reliability and routing operation. We believe that a report about real deployments, especially in this kind of harsh environment, can significantly contribute to provide useful insights and provide guidelines for other deployments.

[5] Maddalena Nurchis, Mikko Valta, Jouni Hiltunen, "Adaptive energy-aware duty cycle scheme for Wireless Sensor Network", ongoing work
Abstract draft – Wireless Sensor Networks are widely employed in many application scenarios, including environmental monitoring, public safety and structural building control. One of the main limitations of this kind of deployments is energy consumption, as sensor nodes are usually battery-powered and the need for battery replacement should be minimized as it is demanding in terms of cost and time. In this paper, we propose a novel adaptive duty cycle scheme, aimed to maximize battery lifetime of each sensor by defining the specific sleeping period according to network synchronization and node application requirements.

III – ATTENDED SEMINARS, WORKHOPS, CONFERENCES

ABCDE Seminar October 31 - November 1 - Athens, Greece

IV – RESEARCH EXCHANGE PROGRAMME (REP)

REP 1

- Fraunhofer FOKUS, Automotive Services and Communication Technologies Competence Center, Berlin
- Dr. Ilja Radusch
- 19 – 23 May, 2014
- Presentation of my PhD and Postdoc research activity and interests; discussion about ongoing projects and potential collaboration; simulation of application for vehicular networks.

REP 2

- Swedish center for Informatics and Mathematics (SICS), Stockholm
- Dr. Bengt Ahlgren
- 23 – 27 June, 2014
- Talk about my research activity of the last years; discussion with many team members about team research topics, common interests and potential collaboration.