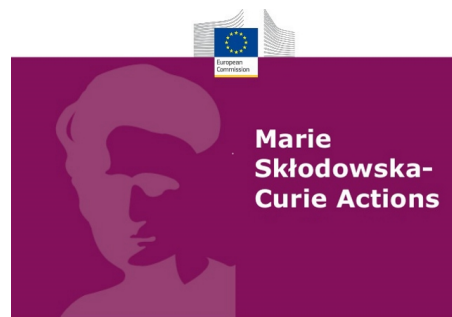
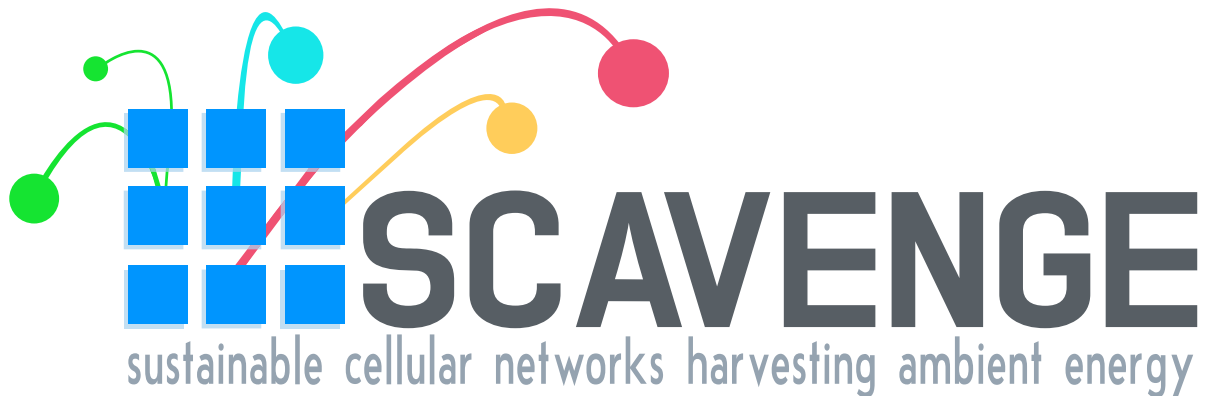


# SCAVENGE NEWSLETTER NO. 3

**H2020 SCAVENGE** (<http://www.scavenge.eu/>)

Funded by the EU in the framework of the H2020 Marie Skłodowska Curie Action - Innovative Training Networks.

1. **Call:** H2020-MSCA-ITN-2015
2. **Acronym:** SCAVENGE (project No. 675891)
3. **Duration:** 48 months
4. **Start date:** 2016-02-01
5. **Project Coordinator:** Paolo Dini - CTTC
6. **Project Officer:** Nina Poumpalova - REA



## SCAVENGE Newsletter No. 3

### In This Issue

- At the peak of our research
- Training goes on ...
- Stay in touch with us
- News from the ESRs

### Our partners



## SCAVENGE newsletter no. 3

### At the peak of our research activity

Once training is concluded, with 2018, our ESRs have been fully and productively committed to their research. Most of them have presented their work at top-tier international conferences and workshops, such as IEEE PIMRC 2018 (Bologna, Italy, September 2018), IEEE ICC 2018 (Kansas City, USA, May 2018) and IEEE GLOBECOM 2018 (Abu Dhabi, United Arab Emirates, November 2018). To date, within the SCAVENGE network 8 journal papers have been published, some in excellent venues such as *IEEE Access* and *IEEE Transactions on Green Communications and Networking*. Moreover, 31 additional papers were published at workshops and conferences. For details about our publications, see the [SCAVENGE publications page](#). Most secondments ended in 2018, and the ESRs are now back to their home institutions. A few secondments are still ongoing, e.g., F. Conceição (ESR02), D. Temesgene (ESR04), N. Piovesan (ESR05). In general, in 2018 the ESRs have been working towards publishing their latest results in prestigious journal papers, and another round of submissions should occur before summer 2019. In 2018, two ESRs have received a **Best Paper Award** for outstanding contributions, at IEEE GLOBECOM 2017 (ESR06, best paper in the Green Communications Systems and Networks Symposium) and IEEE WCNC 2018 (ESR09, Best Student Paper across all papers in the conference). Finally, as part of SCAVENGE, special sessions were organized at IEEE WCNC 2018 and IEEE PIMRC 2018.

### Training goes on ...

Although SCAVENGE training schools all successfully took place in 2016-2017, a vivid training activity has been continued in 2018 with the co-organization of the Summer School of Information Engineering in Brixen. This school has been co-organized by the Department of Engineering at the University of Padova and SCAVENGE senior researchers, addressing selected topics on sensors, signal processing, deep learning and applications.

A group picture from the Brixen school follows :-)



### Stay in touch with us

The perhaps easiest and most entertaining way to see what's going on is through our [YouTube channel](#).

There, you can find the lessons from our first three schools and much more, including: video lessons & tutorials, news from the students, technical

achievements, talks to public events, etc.

[Back to Contents](#)

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## News from the ESRs

### Ibrahim Fawaz (ESR01)



The explosive growth of mobile communications and Internet of Things (IoT) driven by the huge number of connected devices and resource-hungry mobile applications is increasing significantly the demands for high-volume delay-sensitive data traffic, requiring thus intensive computation and leading to high energy consumption. However, this expansion of wireless services is still restrained by mobile terminals limitations in terms of processing capacity, storage and energy. My thesis aims at studying optimal data transmission policies with offloading functionalities by leveraging on devices' energy harvesting capabilities in order to guarantee better performance in terms of energy consumption, packet error rate, latency, etc. During the first period of the thesis, we have addressed this network optimization problem. In particular, we have investigated the joint optimization of resource scheduling and computation offloading for mobile networks, where EH-enabled devices are wirelessly connected to nearby BSs, which can be endowed with some computational capabilities. The main contribution of this work is the introduction of a strict delay constraint instead of the average delay constraint used in prior work. This activity has resulted in three accepted papers at IEEE GLOBALSIP 2017, IEEE ICC 2018 and IEEE ICT 2018. As all the previous work considers a perfect Channel State Information (CSI) at the mobile terminal, an extension that we are studying is to check the robustness of our policy based on an estimated value of the channel, and then to adapt our transmission policy to the case of an unknown channel by the terminal. On

the other hand, I spent the last five months at Imperial College, London, to study *deep learning techniques* and apply them in my work. This secondment gave me the chance to grow technically and to collaborate with other important institutions.

*Overall, working within the SCAVENGE project provided me with a unique opportunity to gain professional research experience and strong analytical and synthesis skills, provided me with a good set of technical and non-technical skills and prepared me with the necessary expertise to dive into both the industrial and academic fields at the end of my thesis.*

### Filipe Conceição (ESR02)



Year 2018 was very very intense! It was a year to finalize ongoing research, start a new research topic, enter the world of machine learning and start a secondment period. All of that with a Scavenge Project school and a poster workshop in the middle. Technically, an energy model for IoT devices has been developed taking into account both networking and security tasks. Conclusions were drawn in regards to security aspects of networking. This resulted in a publication at IEEE PIMRC 2018, which was presented in the beautiful city of Bologna. Then, I started working on the application of machine learning techniques to security in device-to-device (D2D) communications under the guidance of Prof. Michele Rossi from Padua University. The goal is to save energy by applying security features dynamically, when they are required. Initial ideas were discussed during the Scavenge meeting in Barcelona (Sept. 2018), during the poster session and work is currently under full development.... *(continues on next page)*

[Back to Contents](#)

## Outline

### Our vision

- Energy sustainability is key to future mobile networks due to their foreseen capacity upsurge.
- SCAVENGE introduces the concept of *Sustainable 5G Mobile Network*.
- Environmental energy can be used to power the mobile system elements like base stations, mobile terminals, sensors and machines.

### Our mission

- SCAVENGE's objective is to create a training network for early-stage researchers (ESRs) who will contribute to the design and implementation of eco-friendly and sustainable next-generation 5G nets.
- SCAVENGE encompasses theory along with the optimisation and proof-of-concept implementation of base stations and mobile elements as well as their integration with the smart electrical grid.

### Our team

- The attitude of SCAVENGE's industrial partners towards the strong investment in R&D and their strategic vision are fully aligned with the mission of this project.
- The ESRs will have a unique opportunity towards professional growth in light of dedicated cross-partner training activities and through the interaction with the international Partner Organisations, which also include relevant stakeholders in the envisioned market.

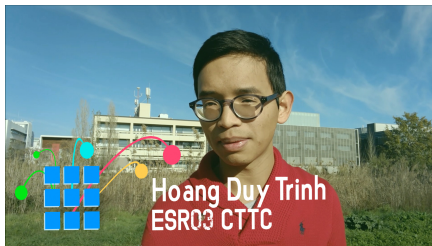
[Back to Contents](#)



(from previous page) ...Finally, towards the end of the year, a secondment period started at Toshiba Research Labs in Bristol, UK. The goal is to gather knowledge based on their expertise in industrial research, use their testbed and simulator knowledge and experience and apply those skills to prototype IoT devices running the ideas that have been developed.

*Scavenge has proven to be a network of people with great knowledge, professional and kind, wanting to cooperate and doing everything to make the project a major research success. Working alongside them made me grow immensely in all aspects required to produce good research. I am happy to be part of this team, and 2019 will be an even more intense year and I am sure that will mean growing even more.*

### Hoang Duy Trinh (ESR03)



2018 has been a great year for my professional growth: I have been hosted to University of Maryland from October 2017 to February to work with Dr. Ulukus, and his research group on energy harvesting models for communications systems. It has been a great opportunity to work alongside such expert people on this topic, and moreover, it gave me the chance to fully appreciate the American academic environment. At the moment, my research topic is focused on analyzing the mobile traffic that comes from real scenarios. We have developed a methodology to gather network and traffic information from different base stations, without harming the user privacy and security. The collection of a large dataset was the first step to create a mobile traffic model: to this end, we are studying the potential of recurrent neural networks, a novel machine learning technique that shows outstanding performance for traffic prediction. Preliminary results were published and presented at IEEE PIMRC 2018 in Bologna, Italy, in September 2018. The next steps are to deepen

the traffic analysis to an app-based level: the goal here is to try to understand and predict which apps are currently running on the user's devices, without breaking any encrypted channel.

*The SCAVENGE training network facilitates the connection between the researchers involved: part of the dataset collection has been accomplished working with ESR 06. We expect to submit a journal paper at the beginning of 2019. Moreover, with ESR 14, we are initiating a couple of works on the topic of discontinuous receiving (DRX), which is an important feature for energy saving in next generation networks.*

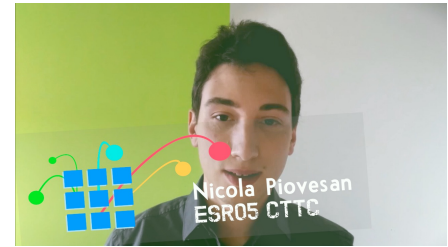
### Dagnachew Temesgene (ESR04)



In year 2018, a study of optimal placement of functional split options for the scenario of energy harvesting virtual small cells has been carried out. Formulation of the optimization problem and its solution by applying dynamic programming, shortest path search in particular, was achieved. A paper with the description of the approach and simulation results was presented at the IEEE VTC-Fall 2018 conference held in Chicago, USA. Moreover, an extension of the study that focuses on the application of reinforcement learning on functional split placement was completed, and the results were presented at the IEEE PIMRC 2018 conference held in Bologna, Italy. These conferences were useful not only to get important feedback on future work, but also to improve my presentation and communication skills. In addition to these conferences, a joint journal paper, together with ESR 05, has been submitted to IEEE Access on the methods of ensuring energy sustainability in HetNet and MEC enabled mobile networks. Currently, a study on the application of fuzzy Q-learning and deep reinforcement learning is underway, targeting journal and conference publications. Moreover, a secondment at

Imperial College London is planned from March, 2019 to September 2019.

### Nicola Piovesan (ESR05)



In the last year, I continued investigating the problem of the increased power consumption due to the augmented system capacity required by 5G networks. This requirement will be met by deploying more network elements, in particular small cells, in a scenario that is usually referred to as "ultra-dense". Specifically, I focused my research on the management of self-sustainable small cells powered by renewable energy. The problem of minimizing the grid energy consumption and maximizing the system performance can be solved by optimally switching ON/OFF the small cells. Furthermore, additional savings can be achieved by computational offloading some of the network functions. To this purpose, I collaborated with Dagnachew (ESR-04) to come up with a first analysis of the optimal load control of small cells in this scenario, and the results have been presented to the IEEE VTC conference in Chicago (USA). We also explored the possibility by the small cells to share their exceeding energy with other network elements. We analyzed the optimal dimensions of the harvesting/storage devices, the bounds on the grid energy consumption and the economic costs. A journal paper has been recently submitted. In the last year, I also worked on the classification of cities based on their energy harvesting characteristics. I proposed an unsupervised method to learn hidden features of the solar energy generation from a photovoltaic system that may give a more accurate characterization of the process. This work has been presented to the IEEE PIMRC conference in Bologna (Italy). In February 2019, I started my secondment at Nokia Bell Labs in Dublin (Ireland). During the secondment, I plan to extend my analysis by considering

more realistic constraints in the scenario I am studying and exploit machine learning techniques to design online algorithms for the load control of small cells.

*As a final remark, the interactions with other ESRs and the joint works with them (i.e., deliverables and papers) have been a great opportunity to improve my team working skills.*

#### Angel Fernandez Gambin (ESR06)



I started 2018 moving to CTTC as my secondment period. There, I have been working in collaboration with ESR03 in the design of data analytic techniques for 5G mobile traffic. Specifically, a journal paper on mobile traffic classification towards LTE physical channel fingerprinting has been done as a major outcome. Meanwhile, I was invited to attend the IEEE ICC 2018 conference to receive the **best paper award** in Green Communications Systems and Networks Symposium for my contribution in IEEE GLOBECOM 2017. A major journal extending this contribution has been published, where pattern recognition and foresighted optimization are put together to intelligently allocate and route energy across a sustainable mobile network powered by solar energy. Moreover, within this topic, I presented a joint work with ESR07 at IEEE WCNC 2017, about energy cooperation for sustainable IoT services within smart cities. Then, I focused together with ESR11 on the integration of energy harvesting mobile networks within a Mobile Edge Computing (MEC) paradigm. With it, computing and communications are performed at the network edge, i.e., at the base station site, where computation resources are in the form of virtual machines co-located in a local MEC server. Algorithms and strategies to jointly manage energy and computation resources, decreasing the energy consumption while guaranteeing the Quality of Service in the net-

work have been addressed. Contributions at the IEEE PIMRC 2018 conference and Wireless Communications and Mobile Computing journal are the main outcomes. Currently, smart energy management strategies with the goal of diminishing the cost incurred in the energy purchases from the power grid are under investigation. This is achieved by intelligently controlling the amount of energy that base stations buy from the electrical grid over time, by accounting for the harvested energy, the traffic load, and hourly energy prices. Pattern forecasting and adaptive control are combined to this end. A first contribution has been presented at IEEE GLOBECOM 2018, and a journal extension of this work is ongoing.

*In short, it has been a fruitful year, full of work and new experiences, which have allowed me to grow professionally and to better understand the research sector.*

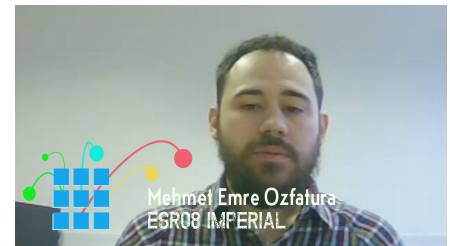
#### Elvina Gindullina (ESR07)



From January to August 2018, I was a part of Worldsensing's innovation team. Worldsensing is a globally active IoT company located in Barcelona (Spain), that provides IoT-solutions for traditional industries and cities, and operates over 50 countries. Together with Worldsensing we studied and tested energy alternatives available for residential or industrial buildings. Worldsensing developed an IoT monitoring device powered by solar energy deployed on a building close to Barcelona. The technology is supported by Worldsensing's wireless monitoring system for remote assets and infrastructures, *Loadsensing*. I provided the theoretical analysis of the *Loadsensing* operation (state of charge), powered by a solar panel, taking into account its energy consumption, battery characteristics, sampling rates, location and characteristics of the solar panel. Based on it, together with Prof. Xavier Vilajosana

(Universitat Oberta de Catalunya), we studied different sampling strategies for an energy harvesting data-logger powered by a rechargeable battery, where we derived the most effective sensing/transmitting strategy in terms of data accuracy and energy consumption, taking into account sampling rate limitations. In other respects, at Worldsensing I was a part of a professional and innovative team, where I gained the research experience in the industrial environment. I learned how to manage/plan my work within an agile system, do estimations of the required efforts, and understand real industrial requirements. During 2018, I presented two papers at IEEE WCNC 2018 held in Barcelona, Spain: "An Optimization Framework for Energy Topologies in Smart Cities", where we propose to represent a Smart City as a common distribution space of information and energy, that can be considered as a system-of-system topology; and "Energy Cooperation for Sustainable IoT Services within Smart Cities", where we study energy cooperation in an Internet of Things (IoT) scenario. The latter was written in cooperation with ESR06.

#### Mehmet Emre Ozfatura (ESR08)



In 2018, as a part of the SCAVENGE project, I have worked at the University of Maryland under supervision of the Prof. Sennur Ulukus. This secondment was a great opportunity for me and has provided valuable experiences. During the secondment, we have focused on distributed computation architectures and our aim was to utilize different coding strategies to achieve communication efficient and straggler tolerant distributed computation frameworks. We have submitted our results to ISIT 2019, DSW 2019, ICASSP 2019 (accepted) conferences. In 2019, our plan is to extend our research to edge learning framework in wireless networks and to also study energy harvesting edge comput-



ing nodes.

*The SCAVENGE project provides collaboration opportunities with other researchers working in similar areas, hence we are also seeking collaboration with other researchers to work together on designing edge learning frameworks for energy harvesting networks.*

#### Nitish Mital (ESR09)



In the year 2018, I presented a paper at IEEE WCNC, which won the **best student paper award**. The paper was titled “coded caching in a multi-server system with random topology”. I had my secondment from June to September in New York University with Prof. Elza Erkip. The experience was exciting. There was a lot of industry collaboration within the NYU wireless group, and there was the fourth workshop of NSF mmWave RCN held in NYU during my time there. Besides the academic advantages of collaborating with Prof. Erkip in the highly dynamic NYU wireless, living in New York for 3 months and indulging myself in the New York lifestyle, and also visiting MIT campus in Boston, made my stay exciting. I presented a paper at IEEE ITW held in China. The paper was titled “Storage-Repair Bandwidth Tradeoff for Wireless Caching with Partial Failure and Broadcast Repair?”. That workshop had many new interesting results in active areas of research, and introduced me to a couple of ideas which came in handy for my next paper submitted to IEEE ISIT, titled “Practical Functional Regenerating Codes for Broadcast Repair of Multiple Nodes?”.

*Being in the Scavenge Network and Imperial College has provided me with the financial resources to be able to attend conferences and secondments which helped me to grow professionally, and the necessary training schools needed for a good research output.*

#### Vianney Anis (ESR10)



The main focus of my research for the past year has been on the implementation of multi-carrier systems on software defined radio (SDR) platforms. Moving toward this goal, I joined the Telecommunications Research Laboratory of Toshiba in Bristol (UK) for a nine months secondment from April 2018. During this secondment, I was able to benefit from the experience in SDR implementation of researchers from Toshiba, while sharing my own knowledge on implementation of signal processing algorithms on various types of platforms. My time in Toshiba has allowed me to develop an experimentation process that will allow me in a near future to compare the power consumption of various multi-carrier designs implemented on an FPGA-based SDR platform, both in simulations and on a real device. In April 2018, I presented my work on equalisers implementation in relation to power consumption for over-sampled FFT-modulated filter-bank multi-carrier systems at IEEE WCNC. Throughout the year, I carried on with my work on wavelet-based filter bank as well as heterogeneous network optimisation with results to be published soon.

#### Thembelihle Dlamini (ESR11)



I am Dlamini Thembelihle (Lihle), a member of the SCAVENGE research group as ESR11 and my research focuses on the application of machine learning and control techniques to edge computing systems with the aim of minimizing energy consumption using energy management procedures, and then enabling energy

self-sustainability in mobile networks with the use of energy harvesting systems and energy storage devices. During year 2018, I was on secondment at the University of Padova, Department of Information Engineering, Italy. The outcome of my research work was a conference paper titled “Online Resource Management in Energy Harvesting BS Sites through Prediction and Soft-Scaling of Computing Resources” published at the International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC 2018) which was held in Bologna, Italy. This was followed by a Journal, which is an extension of the conference paper, and it was published to the Wireless Communications and Mobile Computing (WCMC) journal.

*During my secondment, I have improved my mathematical modeling and scientific paper writing skills.*

#### Pavlos Triantaris (ESR12)



Owing to my late entry into the SCAVENGE programme, my secondment at Imperial College London has not taken place yet. However, I am very satisfied with the time that I have had the privilege of spending under Toshiba Research Europe Ltd. The Bristol Laboratory team has undeniably provided my research endeavours with high-quality equipment and attentive supervision. My first research paper under SCAVENGE, titled “Automatic Modulation Classification in the Presence of Interference”, was drafted and submitted for review to EUCNC 2019, which shall take place in Barcelona. Until that point, presentation of my research

took place mainly in presentations for SCAVENGE and ICL. Given that PhD study path is a highly demanding task, I hold that it shall be proven crucial for my professional development as an engineer.

*Of course, being part of the SCAVENGE project has provided a valuable opportunity to familiarise myself with an academic and an industrial environment, as well as continuous inspiration and support.*

**Ioana Suci (ESR13)**



In June 2018, I joined the University of California, Berkeley, for 4 months, as part of the Scavenge secondment, where I had the opportunity to work with very talented people in an exceptional research environment. Under the direct supervision of Prof. Kristofer Pister, my work focused

on exploring and developing synchronization algorithms for a new generation of chips for IoT. During 2018, our research was presented at three conferences: the IEEE Wireless Communications and Networking Conference (Barcelona, Spain), the International Conference on Ad Hoc Networks and Wireless (St. Malo, France) and the IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (Bologna, Italy).

*All the events organized within Scavenge, including training, secondments and the collaboration opportunities it creates, make it an amazing project that continuously contributes to the professional growth of its students.*

**Soheil Rostami (ESR14)**



Year 2018 was very fruitful for me, I had an amazing opportunity to do my secondment at CTTC, where I have been conducting research under supervision of Dr. Paolo Dini and Dr. Sandra Lagen. The experience is very interesting, because I learn on a daily basis, a lot about optimization, machine learning, and general problem solving techniques. As a result of my collaboration with CTTC, we achieved some amazing results regarding a new wake-up scheme for next generation mobile systems, answering challenging questions such as how to configure the wake-up scheme's parameters, and in which scenarios the scheme is effective. Furthermore, we presented our work in top-tier conferences such as PIMRC and GLOBECOM. With the help of my friends in Scavenge, I am working on deep learning methods for traffic prediction with application to wake-up scheme design.

*By the end of project, I will try to learn some implementation tools for machine learning techniques such as Keras and tensorflow, and hopefully start applying for jobs in both industry and academia. Last but not least, I am learning how to write research proposals at CTTC, for future research grant applications.*

[Back to Contents](#)