Scalable Localization-enabled In-body Terahertz Nanonetwork

Reporting

Project Information

ScaLeITN

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Periodic Reporting for period 1 - ScaLeITN (Scalable Localization-enabled In-body Terahertz Nanonetwork)

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Summary of the context and overall objectives of the project

The main scientific goal of the ScaLeITN project was to propose a terahertz-operating in-body nanonetwork that features localization and two-way communication capabilities. Such a network is envisioned to eventually enable a variety of novel healthcare applications ranging from early (localized) detection of viruses, bacteria, cancerous cells and tissues, to targeted drug delivery and nano surgeries. For enabling the above applications, nano-machines comprising an in-body

nanonetwork are envisioned to flow through the body, take actions at certain locations or upon commands, and communicate results to a more powerful body-area network. Given the small sizes of these nanodevices, harvesting surrounding energy (e.g. from heartbeats or blood currents) was envisioned to be their sole powering option. Due to their constrained energy and tiny form factors, these nanodevices were assumed to be passively flowing, i.e. without the possibility of mechanical steering toward the target locations. To support controlling the nanodevices upon reaching their target locations, there was intuitively a need for knowing their current locations. Equally intuitive, there was a need for communication between the outside world and the nanodevice (e.g. for issuing control commands), as well as between the nanodevice and the outside world (e.g. for delivering device's readings). One of the most promising enablers for communication in such scenario is to utilize electromagnetic signals in the terahertz frequencies. This is because the communication in these frequencies allows for tiny transceiver and antenna form-factors, the prime requirement for in-body nanodevices. However, the terahertz band has its peculiarities, primarily pertaining to high attenuation and spreading loss. Combined with constrained powering of nanonodes relying only on energy harvesting, communication between the body area network and the in-body nanodevices was all but clear at the time the ScaLeITN project was conceptualized.

At the same time, the main educational and career development aims of the project were to expand the existing set of expertise of the MSCA fellow. This was a rather heterogeneous aim, which included i) enhancing the scientific portfolio of the fellow along a set of complementary yet heterogeneous technical domains, ii) obtaining first experiences in supervision of the PhD, MSc, and BSc students, as well as in teaching at the university level, iii) organization of scientific events with the aim of enhancing the visibility of the fellow and the project, iv) enhancing the fellow's understanding of the possibility of the valorisation of the main results of the project, as well as enhancing the his expertise in terms of developing scientific proposals and acquiring further funding.

Work performed from the beginning of the project to the end of the period covered by the report and main results achieved so far

The ScaLeITN project resulted in the following publications:

- F. Lemic et al.: "Localization in Power-Constrained Terahertz-Operating Software-Defined Metamaterials", ELSEVIER Nano Communication Networks Journal, 2021
- F. Lemic et al.: "Survey on Terahertz Nanocommunication and Networking: A Top-Down Perspective", IEEE Journal on Selected Areas in Communications, 2021
- F. Lemic et al.: "Toward Location-aware In-body Terahertz Nanonetworks with Energy Harvesting", submitted for publication, 2022
- R. Asorey-Cacheda, F. Lemic, et al.: "Nanorouter Awareness in Flow-Guided Nanocommunication Networks", 17th IEEE International Conference on Wireless and Mobile Computing, Networking and Communications (WiMob) Workshops, 2021
- Y. Wu, F. Lemic et al.: "A Sensing Integrated DFT-Spread OFDM System for Terahertz Communications", 93rd IEEE Vehicular Technology Conference (VTC-Spring), 2021
- Y. Wu, F. Lemic et al.: "A Non-Uniform Multi-Wideband OFDM System for Terahertz Joint Communication and Sensing", 93rd IEEE Vehicular Technology Conference (VTC-Spring), 2021

- F. Lemic et al.: "Toward Localization in Terahertz-Operating Energy Harvesting Software-Defined Metamaterials: Context Analysis", 7th ACM International Conference on Nanoscale Computing and Communication (NanoCom), 2020

The fellow has supervised 2 PhD students and supported 7 MSc or BSc theses or internship projects. These efforts resulted in 11 additional publications supported by the project.

The main aim along this objective was to gain new experiences related to the participation and organization of scientific events, enhancing his collaboration network, and enhancing the visibility of the ScaLeITN project and its main results. The main results along this aim include the fellow's participation, as well as presentation of the research achievements at each of the following conferences: IEEE GlobeCom 2020, ACM SenSys 2020, ACM NanoCom 2020, ACM SenSys 2021, ACM MMSys 2022, and IEEE ICDCS 2022. The main aims and outcomes of the project have also been presented in several informal university lectures, guest talks, and seminars at the University of Antwerp, Polytechnic University of Catalonia, Shanghai Jiao Tong University, Technische Universität Berlin, and Polytechnic University of Cartagena.

The fellow also co-founded and acted as a general chair and a leading organizer of the ACM International Workshop on Nanoscale Computing, Communication, and Applications (ACM NanoCoCoA) under the umbrella of the ACM SenSys conference. The workshop significantly enhanced the fellow's collaboration network and the visibility of the ScaLeITN project. Another result worth emphasizing is the guest editorial at the IEEE Transactions on Nanotechnology named “Nanoscale Computing, Communication, and Applications”, which is currently in progress (second round of reviews) with more than 20 received journal papers.

Finally, the fellow has managed to secure a María Zambrano postdoctoral fellowship through a call from the Polytechnic University of Catalonia. The fellowship envisions an eventual tenure track position at the Polytechnic University of Catalonia and can be viewed as a natural continuation of the work carried out during the ScaLeITN project.

Progress beyond the state of the art and expected potential impact (including the socio-economic impact and the wider societal implications of the project so far)

The project eventually resulted in 19 publications. This includes 5 journal articles and two currently under review, 9 conference publications and 3 currently under review. The research enhanced the current state-of-the-art in terahertz nanocommunication and nanonetworking, in-body location awareness, intelligent reflective surfaces, and terahertz joint communication and sensing, to name a few. Through student supervision, the project also made contributions in related domains such as wireless networking for virtual reality and unmanned aerial vehicles. On the career level, the project significantly expanded the heterogeneity of the fellow's skillset. The fellow has gained first teaching experiences at the university level, as well as experience in supervising PhD, MSc, and BSc students in their research projects. The fellow has also gained first experiences with workshop organization, as well as with editorial work at prominent scientific journals. The efforts carried out by the fellow also

strengthened the community on terahertz nanocommunication and nanonetworking for in-body healthcare applications, and can be considered as an additional impact of the project
Finally, the fellow's work during the ScaLeITN project significantly enhanced his collaboration network and allowed him to kickstart new collaboration efforts for acquiring additional funding.

Invited talk at the ACM NanoCom 2020 conference

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