Friedrich-Alexander-Universität Erlangen-Nürnberg
Institute for Digital Communications
Cauerstraße 7
91058 Erlangen

Research Internship in Science and Engineering (RISE)

Improving Source Localization Accuracy in Branched Vessel Networks Using Prior Information

Research Question: Branched vessel networks (BVNs), consisting of interconnected vessel segments that transport fluids, are ubiquitous in both nature and engineering, and across different scales. Examples include the cardiovascular system [1] and sewer networks [2, 3], as shown in Figure 1a) and Figure 1b), respectively.

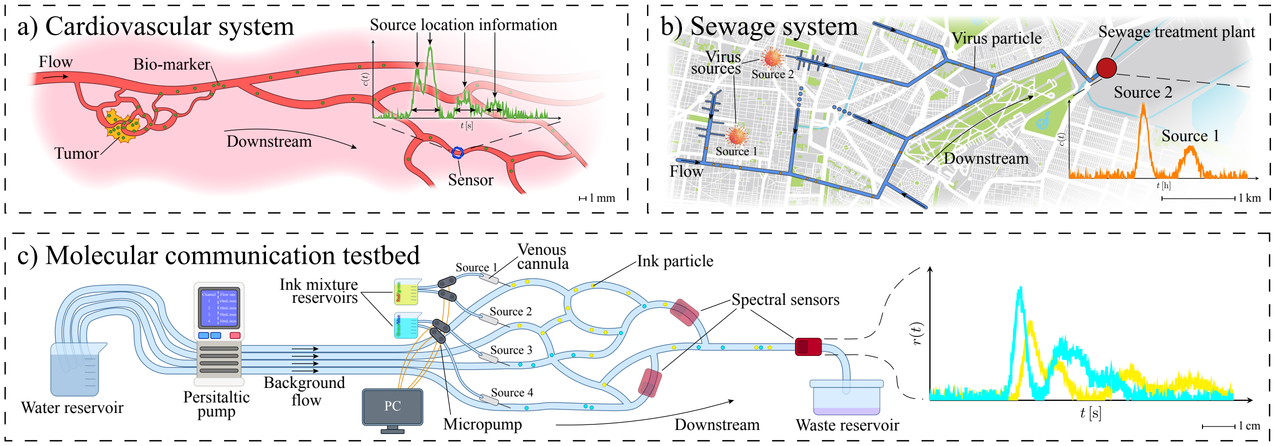

Figure 1: Localization in BVNs in various contexts: a) Inside the cardiovascular system, localization enables early tumor treatment. b) In sewage systems, infectious diseases can be traced back to their source, facilitating targeted countermeasures. c) Testbeds can model the localization behavior of real-world systems across different scales.

In the last few years, engineers from various disciplines have become increasingly interested in inferring the position of particle sources in BVNs from measurements taken by sensors that are distributed throughout the BVN. Such source localization has a variety of interesting use cases: For instance, the localization of tumors emitting biomarkers in the cardiovascular system could enable earlier diagnosis of cancer [1]. Similarly, the feces of individuals infected with certain diseases contain biomarkers that could be used to locate those individuals and thus help contain disease outbreaks [3].

While source localization clearly has the potential to improve human life, it has been suggested in [4] that *naive* localization approaches require a prohibitively large number of sensors to achieve a sufficiently high localization accuracy. However, in many scenarios, sources do not emit only a single molecule type but a possibly unique mixture of molecules. In some cases, there is prior knowledge available about which source emits which mixture: For example, different cancer types are more likely to occur in one body part than another. Since different types of cancer also emit different mixtures of biomarkers, the composition of the molecule (biomarker) mixture also contains information about the location of the tumor.

This raises the following question: *How can the information encoded in the mixture composition help to reduce the number of required sensors and render source localization practically feasible?*

How to Answer the Research Question: We tackle this question using methods from molecular communications (MC), an emerging research area, where tools from *communications engineering* are used to describe the propagation of molecules and the information encoded in them. Recently, our research group has developed and validated a theoretical model to describe the flow in BVNs across different scales using impulse responses. In addition to these theoretical models and simulations, we have access to a mesoscale testbed based on [5], which will be extended in another project to also include BVN structures, as shown in Figure 1c).

Your Contribution: During your stay, you will be involved in both theoretical modeling and experimental work, depending on your specific interests and skills:

- You will extend the existing theoretical models to account for molecule mixtures.
- You will develop new localization algorithms that exploit prior knowledge about location-specific molecule mixtures and evaluate them using the extended framework.
- You will perform measurements in the BVN testbed and use them as additional validation for your localization algorithms.

During your stay, you will be closely supervised by two doctoral researchers with expertise in theoretical modeling of particle propagation, experimental MC testbeds, and localization algorithms. At the end of your internship, you will have the opportunity to present your results to the entire institute. Because you will perform experiments with a testbed in our institute, a virtual internship is *not* possible.

Your Workplace: You will be hosted at the *Institute for Digital Communications (IDC)* at *Friedrich-Alexander-Universität Erlangen-Nürnberg*. IDC is one of the leading research groups in communications engineering in general and in MC in particular. Thus, you will be surrounded by experts in both theoretical modeling of MC systems as well as experts in building experiments. We are located in Erlangen, a city of about 110,000 people, in the south of Germany. Erlangen not only has a very vibrant student life but is also ideally located for day trips into the nearby countryside or to Munich, for example. And, of course, *Berg*, one of Germany's oldest and most famous fairs, will take place in Erlangen in June 2025, which is definitely worth a visit.

Questions? If you have any questions about the internship, please don't hesitate to reach out to us! You can find our contact information below:

SUPERVISORS	Bastian Heinlein, bastian.heinlein@fau.de Timo Jakumeit, timo.jakumeit@fau.de
PROFESSORS	Prof. Vahid Jamali, vahid.jamali@rcs.tu-darmstadt.de Prof. Robert Schober, robert.schober@fau.de
INSTITUTE WEBSITE	https://www.idc.tf.fau.eu

References

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[4] O. Adedoja *et al.*, "A state-of-the-art review of an optimal sensor placement for contaminant warning system in a water distribution network," *Urban Water J.*, vol. 15, pp. 985–1000, Apr. 2018.

[5] A. Wietfeld, S. Schmidt, and W. Kellerer, "Evaluation of a multi-molecule molecular communication testbed based on spectral sensing," *arXiv preprint arXiv:2405.10280*, May 2024.