Palaiseau, December 5, 2022

Post-Doc opportunity – GTO team – COMELEC department

«Acoustic sensing over optical fiber networks »

Context

The concept of a smart city relies on the collection and exploitation of data extracted by many sensors delivering information on circulation of vehicles, detection of human presence and many events affecting the infrastructures (water and gas networks, buildings, bridges and tunnels…). The current approach to collect this information is to deploy a multitude of discrete and dedicated sensors or deploy dedicated distributed optical fiber sensing cables. This deployment has a high logistical cost (installation, energy supply, maintenance). However, telecom fiber optic networks already crisscross current cities: the use of this available infrastructure for the purposes of capturing, locating and identifying vibration events is a very attractive approach. Most of the research works targeting sensing through the telecom infrastructure have replicated distributed acoustic sensing (DAS) solutions, originally used over dedicated sensing cables. They had shown promising results in road/rail traffic supervision [1-3] and in measuring dynamics on the scale of an urban or regional area: near-surface characterization [4-5] detecting high levels of use of certain sites during crisis (as in the current COVID19 crisis) [6-7], and other seismic events.

In DAS and geophysics workshops, researchers regularly highlight that DAS measurements over deployed optical fiber infrastructure are able to provide information on vibrations that are not detectable with conventional discrete sensors such as geophones or seismometers. Despite this positive observation, we believe that sensing through the deployed fiber cables can be drastically improved. The integration of powerful sensing techniques to the network will pave the way for enhanced real-time network monitoring and the provision of valuable data for a multitude of applications.

Work plan

DAS approach relies on the existence of distributed Rayleigh backscattering, an inherent impairment in an optical fiber. The scientific barrier is mainly the low level of Rayleigh backscattering and its randomness. In an optical network, technical

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barriers also come from the heterogeneity of their topologies. For instance, the presence of multimode fibers in some legacy local area networks induce crosstalk among multiple propagating modes that might affect DAS sensitivity. In metropolitan networks, some optical devices can prevent the backscattering generated by the following fiber cables from reaching the interrogator (isolators, routing nodes…). In access networks, the existence of 1-to-N fiber topology (one fiber splitting to N through an optical splitter to serve N end-users) will lead to a localization ambiguity. The resolution of these problems will be at the heart of this project.

We propose to benefit from the deployed optical transmission infrastructure as a network of passive sensors to facilitate the telemetry of a large set of acoustic and vibratory phenomena reaching this infrastructure. Fiber is increasingly deployed in urban and rural areas, often throughout road and rail development projects. FTTx (Fiber To The x=Home, Building,…) networks and local area networks (LANs) are also developing fast, bringing the fiber closer to homes and workplaces to ensure the best quality of transmission and highest data throughput. The reuse of the optical infrastructure, whether through DAS or other sensing techniques, as a distributed vibration sensor, converts it into a neuralgic network enabling the detection of vibrations that propagate via different layers separating the vibration source from the fiber core. Characterization and localization of these vibrations with the highest possible accuracy, followed by their identification using automatic learning algorithms, pave the way for network monitoring and provision of valuable data for a multitude of applications (road/rail traffic supervision, security, monitoring urban dynamics to detect hazards particularly in times of crisis…).

We expect to deliver proof-of-concepts of sensing solutions that can address various sensing scenarios while targeting:

- Zero impact on the quality of service (QoS) of the telecom network;
- Achieving higher sensitivity levels, or wider scope of detectable strains than the state-of-the art and appropriate spatial resolutions for these scenarios.
- Validating our solutions over lab setups and possibly field trials.

Qualifications

- The candidate must have successfully finished a PhD in Electrical Engineering, Optical Communications, Photonics or related domains.
- Knowledge of optical transmission systems and networks is necessary. Knowledge of digital signal processing algorithms involved in communication systems or optical fiber sensors is desirable.
- Skills in DSP programming (through MATLAB or Python) are appreciated
- Strong interest for applied research
- Ability to work in a multi-cultural environment and to supervise interns and/or students during projects

About our lab

The Information Processing and Communications Laboratory (LTCI) is Télécom Paris' in-house research laboratory (130 research professors and 250 PhD students, PostDocs and research engineers). The LTCI was created in 1982 and is known for its extensive coverage of topics in the field of information and communication technologies. The LTCI's core subject areas are computer science, networks, signal and image processing and digital communications.

The Optical Telecommunications Group (GTO) is home to the research programs of eight faculty members and a state-of-the-art laboratory on optical fiber transmission. We conduct advanced research in high-rate fiber-optic transmission, optical network architectures, novel lasers for communications, integrated photonics, and distributed optical fiber sensors.

Duration and Location

- One year starting from February 2023
- Location: Télécom Paris, Institut Polytechnique de Paris, 19 place Marguerite Perey, 91120 Palaiseau, France.

To apply, please send your CV, publication record and motivation letter to elie.awwad@telecom-paris.fr

References

[1] M. Huang et al., "First Field Trial of Distributed Fiber Optical Sensing and High-Speed Communication Over an Operational Telecom Network," in Journal of Lightwave Technology, vol. 38, no. 1, pp. 75-81, 1 Jan.1, 2020, https://doi.org/10.1109/JLT.2019.2935422

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[5] Ajo-Franklin, J.B., Dou, S., Lindsey, N.J. et al. Distributed Acoustic Sensing Using Dark Fiber for Near-Surface Characterization and Broadband Seismic Event Detection. Sci Rep 9, 1328 (2019). https://doi.org/10.1038/s41598-018-36675-8

[6] Lindsey, N. J., Yuan, S., Lellouch, A., Gualtieri, L., Lecocq, T., & Biondi, B. (2020). "City-scale dark fiber DAS measurements of infrastructure use during the COVID-19 pandemic", Geophysical Research Letters, 47, e2020GL089931. https://doi.org/10.1029/2020GL089931

[7] Zhu, T., Shen, J., and Martin, E. R.: Sensing Earth and environment dynamics by telecommunication fiber-optic sensors: an urban experiment in Pennsylvania, USA, Solid Earth, 12, 219–235, 2021 https://doi.org/10.5194/se-12-219-2021