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Environmental Sensing and Detection based on State of Polarization Monitoring in Terrestrial Optical Data Networks

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Telecommunications networks based on optical fiber communication have been vastly deployed in the last years to cope with the increasing traffic demands. They cover wide terrestrial areas with thousands of kilometers of available fiber cables, arranged in meshed, rings or festoon network topologies. Moreover, their operation is becoming more and more software-defined thanks to the definition of open interfaces and data structures, transforming the infrastructure into a crucial commodity able to offer several network services.

Recently, the idea of using existing telecommunications fiber networks as a wide smart grid for environmental sensing is gaining momentum, since optical fiber can be used as an excellent mechanical stress sensors, as several physical effects are impacted by external stress. Distributed acoustic sensing (DAS) techniques deliver extremely accurate and spatially resolved measurements which are the state of the art, for example, in earthquake detection. However, its high cost, need for dark fibers and physical limitations prevent its wide deployment in telecom infrastructure.

In this context, sensing based on state of polarization (SOP) monitoring of optical signals is an attractive solution. SOP is alredy monitored on optical coherent channel receivers for data recovery, although access to this data is usually closed by transceiver vendors. However, it is potentially accessibile on cheaper intensity modulated optical data channels, still widespread in optical networks, especially in the access segment. Also, it can be monitored using dedicated signals which can be transmitted alongside typical data channels. Moreover, SOP sensing does not require bidirectional transmission onto the same fibers and can extend its reach farther than DAS as it supports optical amplifiers, thus improving the compatibility between data and sensing services. On the downside, SOP sensing loses DAS spatial resolution, as it provides an integrated measuremnts over an entire fiber span and extraction of significant event information is complicated by the randomness of fiber birefringence. However, terrestrial networks can offer several SOP sensing sites which can be implemented with far cheaper equipment with respect to DAS or interferometry.

In this work we explore the possibility for wide sensing grids with fiber length scale spatial resolution, which can integrate the information provided by traditional seismic stations networks. In particular, while developed areas may leverage on seismic stations networks, SOP sensing represents a cost effective solutio in emerging economies where telecom infrastructure is already deployed. Another key aspect relates to the development of effective techniques to detect the environemntal events of interest features, such as the earthquakes P/S waves, from the SOP time series. Indeed, especially in the terrestrial networks scenario, anthropic activities act as noise on the monitored SOP evolutions. To this aim, detection based on machine learning techniques is promising, due to the largely vaying characteristic figures of seismic waves. Due to the lack of extensive SOP experimental observations, we have developed simulations tools able to generate SOP synthetic data from realistic strain rates and we show how they can be used to train ML models based on spatially integrated SOP time evolutions.