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Smart Grid Optical Fiber Network for Earthquake Early Warnings

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Optical fiber networks, commonly known for data communications, could be extended beyond their conventional use. In our research, we propose a groundbreaking method by leveraging these existing terrestrial optical networks as wide distributed array sensors for earthquakes early detection. This approach is centered around the use of light polarization changes within the fiber cable, analyzed through a robust machine learning model that provide early warning alerts upon Primary earthquake waves arrival that induce strain, and precede earthquake's destructive Surface waves. Unlike previous methods such as Distributed Acoustic Sensing and Frequency Interferometric Techniques, our approach avoids the use of expensive and specialized hardware. We introduce a centralized smart grid system that exploits the network's existing terrestrial infrastructure, yet ensure cost effective and high efficient network modeling for initiating emergency plans and earthquake countermeasures. Our initial studies started by conducting experimental tests on a deployed fiber ring in Turin, Italy, using commercial Intensity Modulated – Direct Detection transceivers and polarimeters as polarization sensing devices, yield in promising results. Additionally, we identified the Primary waves arrival for a real 4.9 magnitude earthquake struck in the Marradi region, central Italy, with a 98% accuracy rate. This achievement was the result of a python-based waveplate model empowered by machine learning algorithm.

Basically, when an earthquake occurs, networks nodes communicates with a centralized optical network controller that detects alterations in the light's state of polarization by leveraging a pre-trained machine learning model. Upon the model confirmation, the controller activates early warning system in accordance with a predetermined emergency response mechanism. Building up on these findings, our current objective is to explore the impact of earthquake depth on seismic wave characteristics and their influence on light's polarization to further investigate the potential of this advanced smart grid methodology. We aim to analyze real ground motion waves generated by two distinct earthquakes with same magnitudes but different depths. This knowledge is crucial in refining our machine learning model, which in turn will refine model prediction capabilities. Our approach promises more efficient optical network, by transforming the network into long range seismic sensors.