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Mitigation of Atmospheric Duct Interference (ADI) in LTE-TDD Networks: A Machine Learning-Based Approach

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Atmospheric Duct Interference (ADI) causes abnormal long-range radio propagation due to refractivity inversions in the lower atmosphere, resulting in severe uplink degradation in LTE-TDD cellular deployments. This research proposes a data-driven framework to automatically detect, predict, and mitigate ADI while preserving network coverage and uplink quality. The proposed framework was developed using two heterogeneous data sources. Network-side measurement data were obtained from Dialog Axiata PLC, collected from LTE-TDD deployments in the Jaffna Peninsula, with approximately 100,000 time-indexed records from over 580 cells across 111 base stations, including uplink interference statistics, symbol-wise uplink power measurements (UL0-UL13), antenna configuration parameters, and geographical coordinates. Environmental and atmospheric parameters were obtained from the Copernicus Climate Data Store, including temperature, pressure, and humidity profiles used to characterize ducting conditions. After preprocessing and labeling, numerical and categorical features were standardized and encoded using a Python-based pipeline. Class imbalance was addressed using random undersampling, and the data were split into 70% training, 15% validation, and 15% testing sets. Three supervised classifiers—Random Forest, Support Vector Machine, and k-Nearest Neighbors—were trained and evaluated using accuracy, confusion matrices, and cross-validation. Among the evaluated models, the Random Forest classifier demonstrated the most stable performance, achieving the highest test accuracy of 97.8% in distinguishing normal and interference-affected conditions. Feature analysis confirmed that uplink interference levels, symbol-wise power ramping behavior, and spatial indicators are dominant predictors. Upon ADI detection, a coordinated mitigation strategy involving adaptive antenna down-tilting, transmit power adjustments, and coverage compensation from neighboring cells was applied using radio propagation modeling. Simulation results demonstrate that over 70% of ADI-induced coverage loss can be recovered without introducing additional spectrum usage. This research presents an original, scalable solution for intelligent ADI management in LTE-TDD networks and provides a practical foundation for future ADI-aware optimization.

Keywords: Atmospheric ducting interference, LTE-TDD, Machine learning, Network optimization, Uplink interference