Spatio-Temporal Beam-Level Traffic Forecasting Solution

This project presents a robust and production-grade forecasting pipeline for predicting beam-level network traffic in 5G networks. The pipeline integrates deep learning (CNN–BiLSTM–GRU–Attention) and ensemble methods (XGBoost + Ridge regression) to accurately model both spatial and temporal dependencies in network traffic data.

Workflow Summary

The system includes advanced EDA, multi-level feature engineering, hybrid modeling, and meta-learning for optimal generalization. It automatically detects the environment (Kaggle/local), gracefully handles missing files, and scales seamlessly across CPUs and GPUs.

Component	Description
Data Handling	Dual fallback (Kaggle/local), safe loading with exceptions
EDA	Time-series decomposition, rolling averages, congestion mapping, ADF tests
Feature Engineering	Lag, rolling, cyclic, congestion, contextual flags
Deep Learning Model	CNN–BiLSTM–GRU–Attention hybrid with regularization
XGBoost	GPU/CPU compatible structured model
Meta Model	Ridge regression stacked blending
Evaluation	Comparative MAE across NN, XGB, and meta models
Output	Submission CSV + Saved model artifacts

Key Differences: Original vs Improved Version

Feature / Section	Original Version	Improved Final Version
Data Handling	Static CSV paths	Dynamic fallback, safe loading
EDA	Minimal line plots	Full decomposition and congestion mapping
Feature Engineering	Basic lag features	Lag + rolling + cyclic + contextual flags
Scaling & Splitting	Single split	Robust scaling and sequential split
Deep Learning Model	Simple LSTM	CNN–BiLSTM–GRU–Attention hybrid
Callbacks	None	EarlyStopping and ReduceLROnPlateau
XGBoost	Missing/basic	Full-featured with GPU/CPU fallback
Meta Model	None	Ridge regression stacking
Error Handling	Minimal	Comprehensive try-except blocks
Evaluation	Single model MAE	Comparative MAE summary
Output	Basic print	Saved artifacts and formatted outputs
Reproducibility	Not saved	Saved .keras, .pkl, .csv

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