5G Technology for Smarter and Secure Connectivity

Project Report: Advanced Beamforming Optimization for 5G Massive MIMO using Deep Learning

1. Introduction

Problem Statement

This project aims to design and simulate a deep learning-based beamforming algorithm for 5G massive MIMO systems in highly mobile environments. The objective is to optimize signal strength using artificial intelligence techniques such as deep neural networks (DNN) and reinforcement learning (RL).

Objectives

- Implement a deep neural network (DNN) in MATLAB that predicts optimal beam directions.

- Simulate a multi-user MIMO system and compare conventional vs. AI-driven beamforming.

- Use Reinforcement Learning to optimize beam selection dynamically.

2. Methodology

MATLAB Implementation Approach

The simulation uses modular MATLAB scripts and functions, each fulfilling a specific purpose:

- main.m: The main script that executes the complete beamforming simulation pipeline.

- simulate_mimo.m: Simulates the MIMO system environment and generates feature-label datasets.

- dnn_model.m: Trains a deep neural network on the MIMO features for beam direction prediction.

- rl_beam_optimization.m: Applies reinforcement learning for dynamic beam optimization.

- conventional_beamforming.m: Calculates SNR using traditional beamforming methods.

3. Simulation Setup

Key Parameters

Parameter	Value
Number of Users	10
Input Features	User coordinates, channel conditions
DNN Training Epochs	15
DNN Optimizer	Adam
RL Environment	Custom MATLAB RL function
Output Visualizations	SNR plots, training progress, RL logs

Assumptions

- Mobility is simulated via random or pre-defined user movement.

- Channel conditions are assumed based on simplified propagation models.

- Noise is considered for SNR evaluation.

4. Results & Discussion

Generated Figures

- SNR Plot : Beam SNR plot for AI-based prediction from DNN.

-Comparison between AI driven : Comparison plot between conventional and AI-driven beamforming.

- Training Progress: Automatically generated by MATLAB during DNN training.

- Reinforcement Learning Training Monitor: Monitor showing agent's reward and training progress.

Observations

- The DNN effectively predicts beam directions, resulting in improved SNR.

- AI-driven beamforming outperforms traditional methods in various simulated scenarios.

- RL-based beam selection dynamically adapts to changes in environment, improving signal quality over time.

5. Conclusion

Summary

This simulation successfully demonstrates advanced beamforming optimization using deep learning and reinforcement learning in a 5G massive MIMO setup. The DNN model and RL agent both contribute to improved beam prediction and dynamic adaptation in mobile scenarios.

Future Improvements

- Expand simulation to include time-varying and frequency-selective fading.

- Integrate real-world channel datasets for more accurate evaluation.

- Combine beamforming with adaptive modulation for holistic link adaptation.

Appendix

Included Files

- main.m: Main execution script

- simulate_mimo.m

- dnn_model.m

- rl_beam_optimization.m

- conventional_beamforming.m

- plots: results/figures/*.png

- logs: results/logs/*.csv