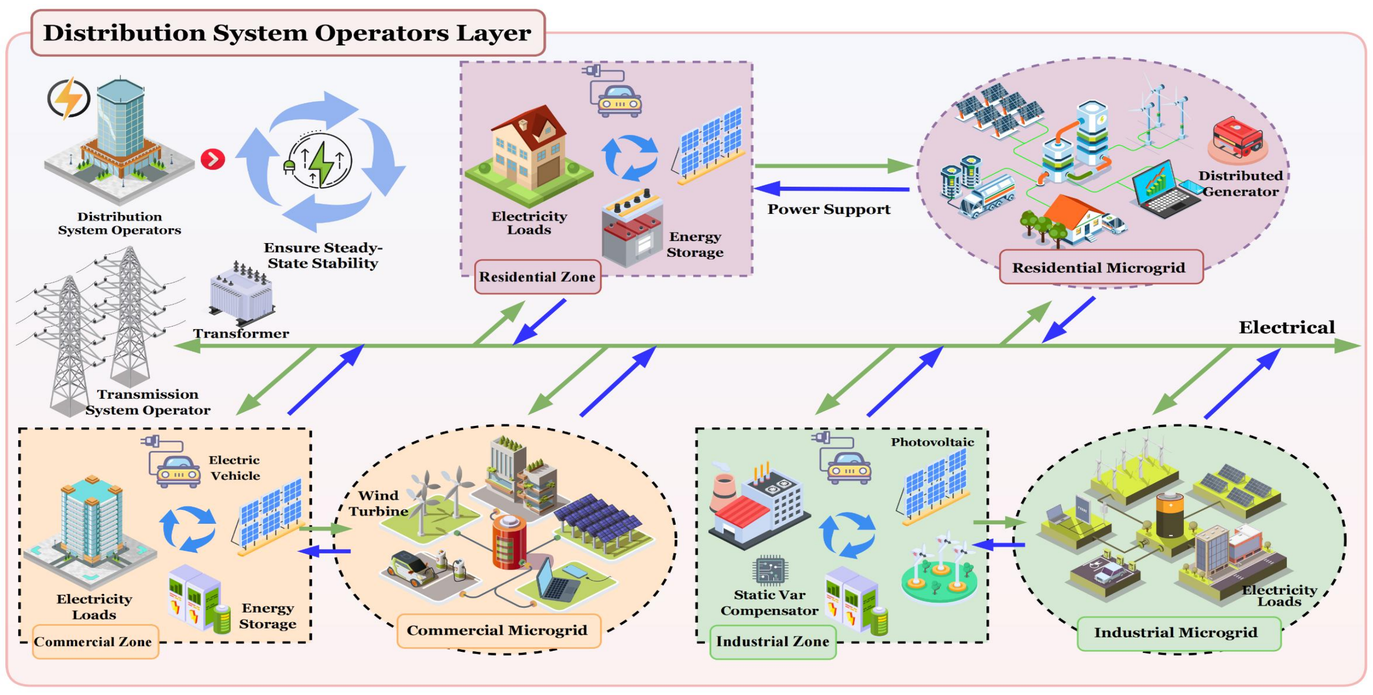
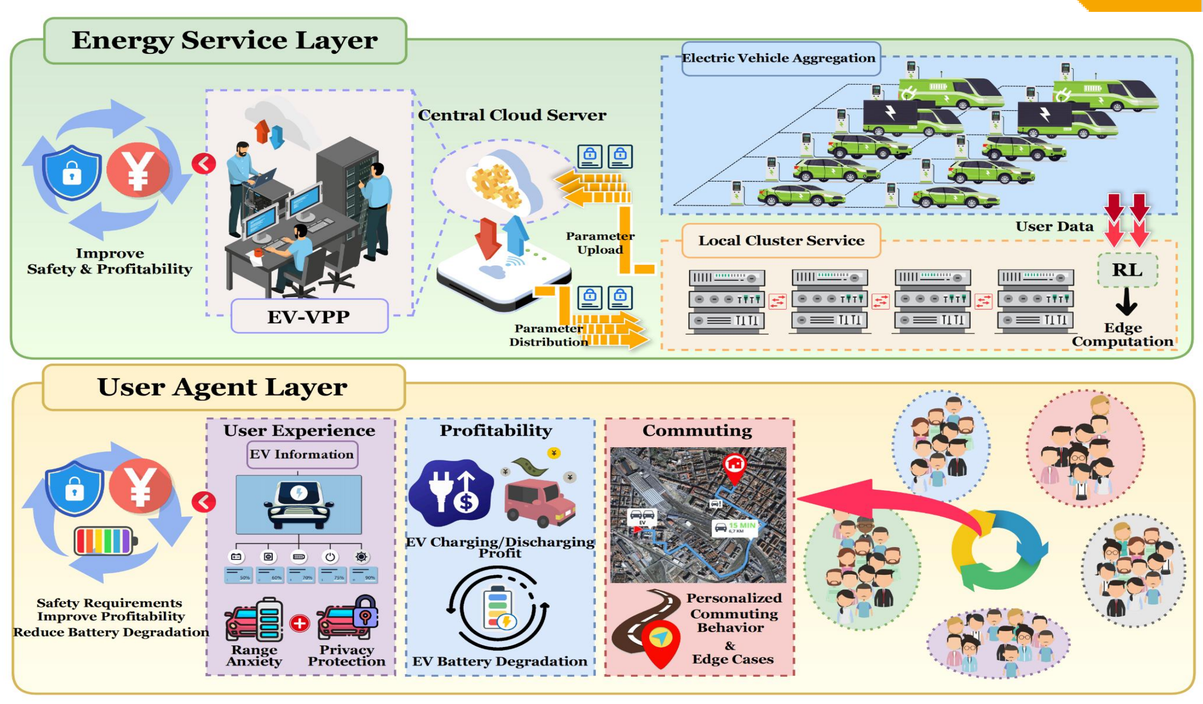
Safe and Economic V2G Scheduling for Multi-Microgrids



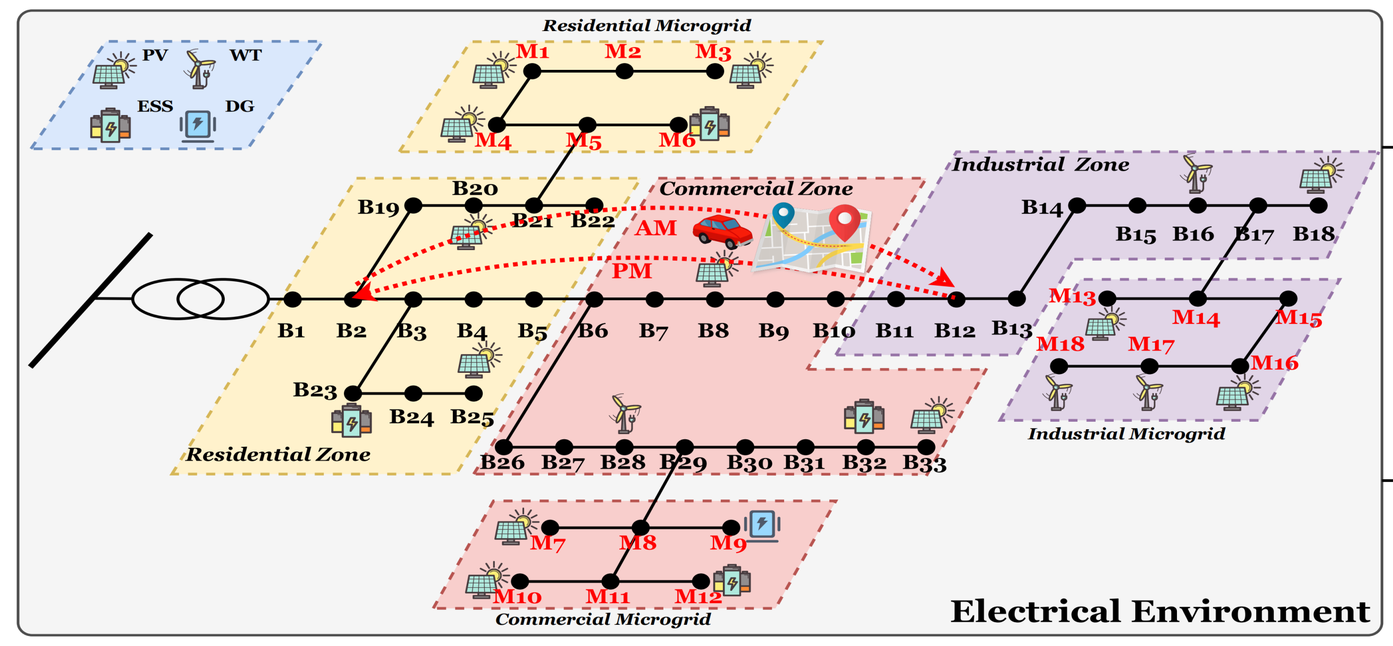


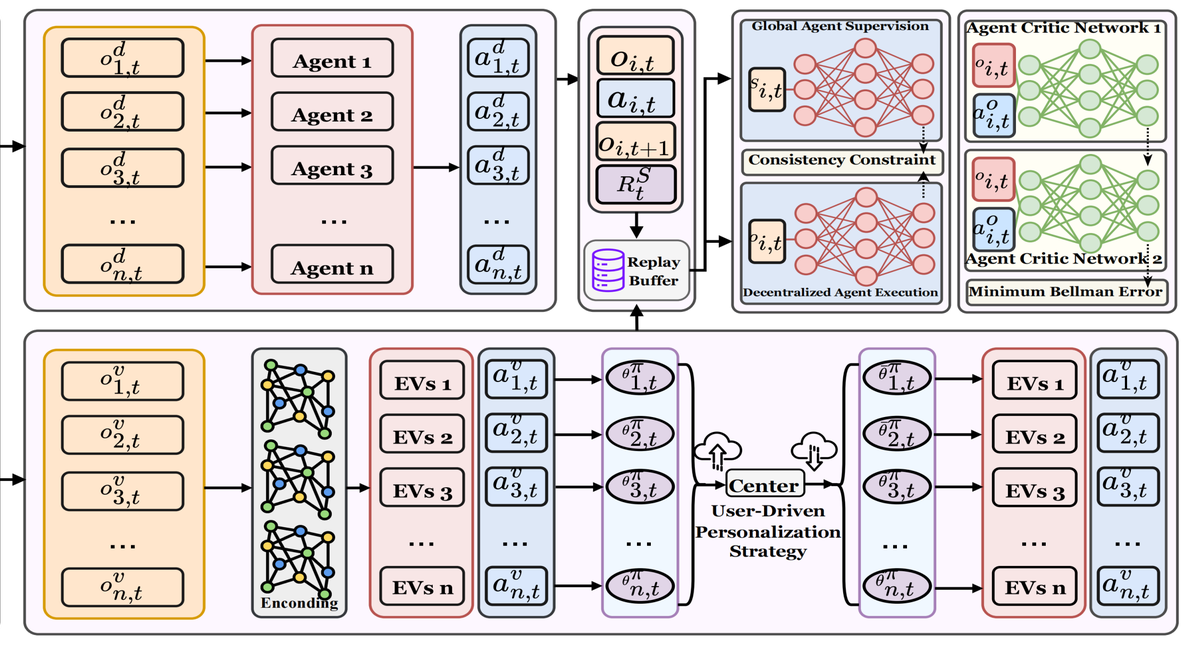
Background

- **Renewable and EV rich microgrids are stressing distribution networks.**
  - ➢High penetration across microgrids tightens voltage and power-flow margins.
  - ➢EV fleets in these multi-microgrid systems enable peak shaving, valley filling, and voltage support (if security, privacy, and user heterogeneity are handled together).

Motivation

- **Existing V2G methods still face three key limitations:**
  - ➢Safety relies on soft reward penalties; topology is treated as static, not guiding policies toward grid safety regions.
  - ➢FedAvg-style learning suffers negative transfer under non-independent and identically distributed users across zones.
  - ➢Rational-user, linear-cost models ignore loss-averse range anxiety and battery aging.
- ■ **A safety aware, privacy preserving, user centric V2G framework is needed.**





Proposed Method

- ■ **We propose HG-FMARL, a hierarchical graph federated multi-agent RL framework for safe and economic V2G scheduling, with three coordinated layers:**
  - ➢Distribution System Operator layer: maintains voltage and power-flow security.
  - ➢EV-Virtual Power Plant layer: aggregates EV flexibility and sends price signals.
  - ➢User agent layer: learns personalized charge/discharge policies.
- ■ **Key technical components:**
  - ➢Graph convolutional network encoder for topology-aware grid features.
  - ➢Kullback-Leibler consistency aligning local policies with a global safety policy.
  - ➢Personalized federated learning for privacy under non-IID data.
  - ➢User Incentive Index for range anxiety & battery aging.

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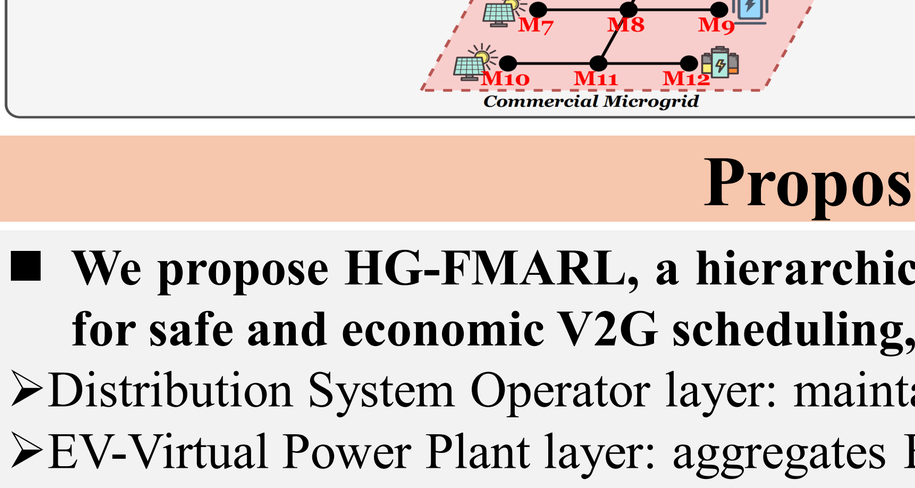
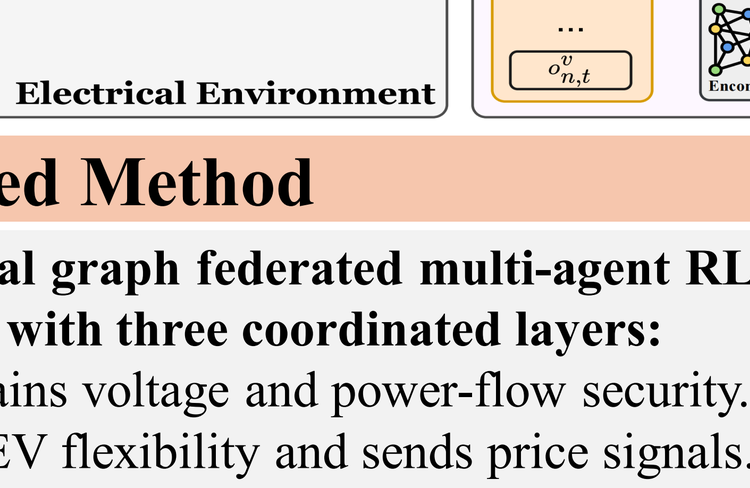
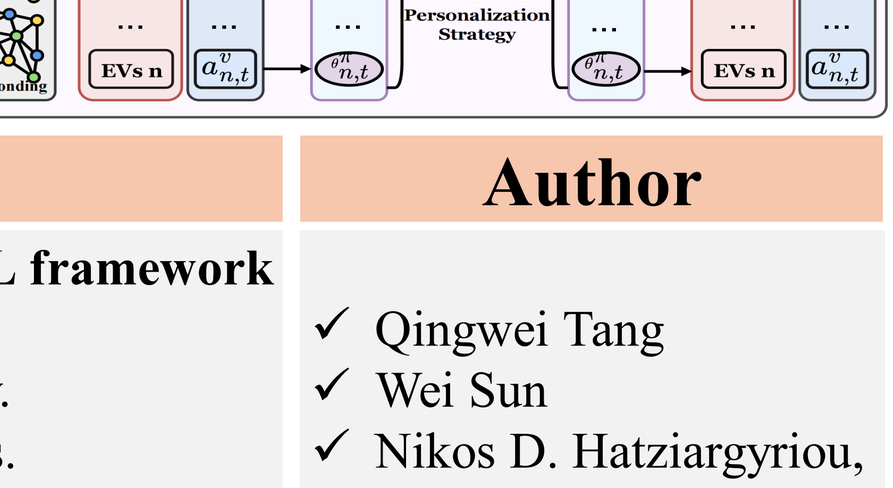
Experiments



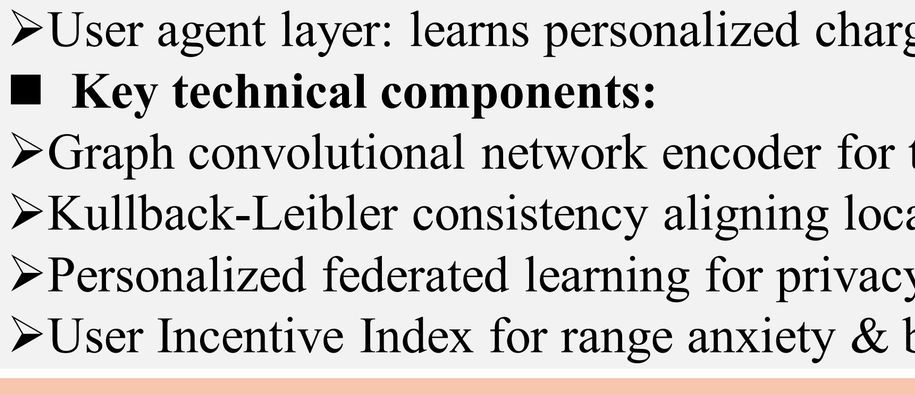
Reward



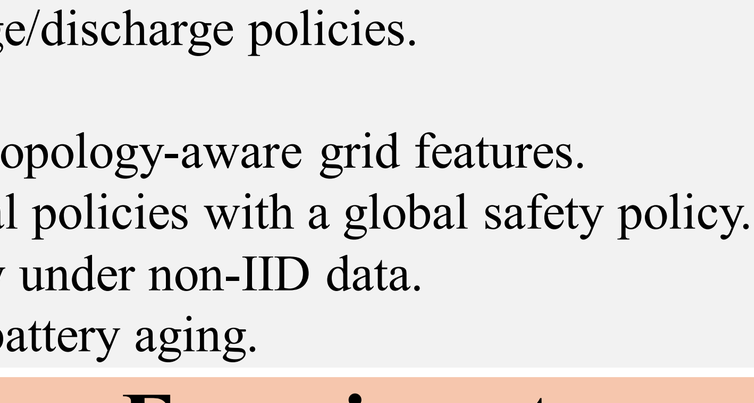
Benefits



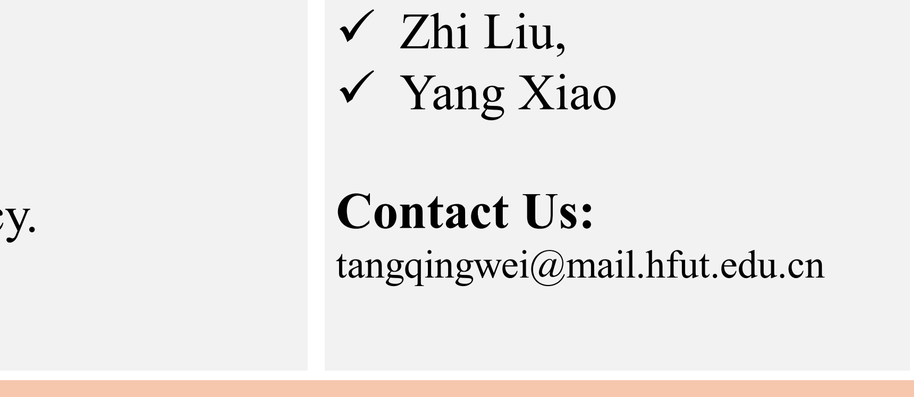
User Incentive Index



Voltage



Power Support



Income Expenditure Composition

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