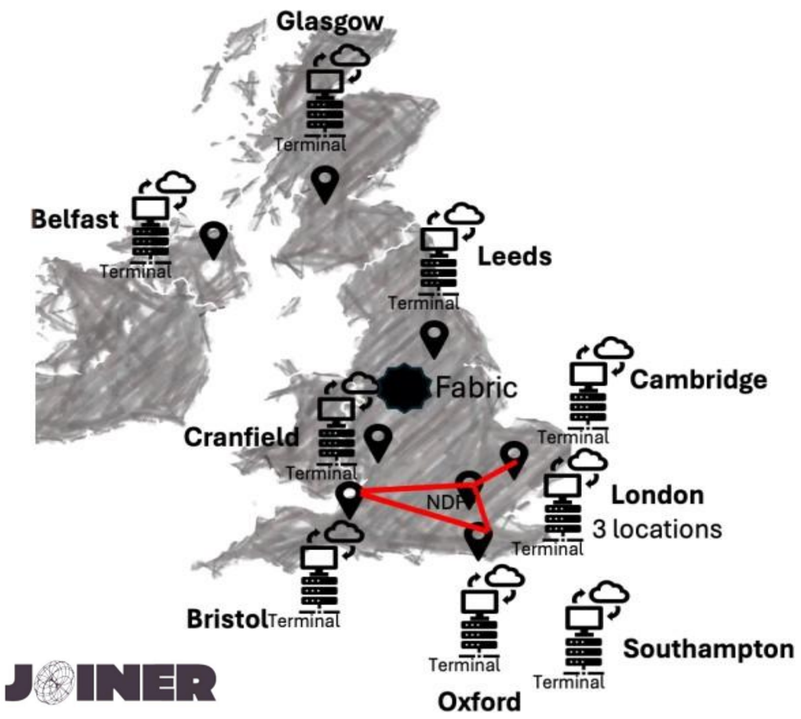
EcoNGN: Embedding Carbon Awareness into Next Generation Telecom Networks

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1. Introduction & Background

1.1 Why Carbon Awareness in Telecom Networks?

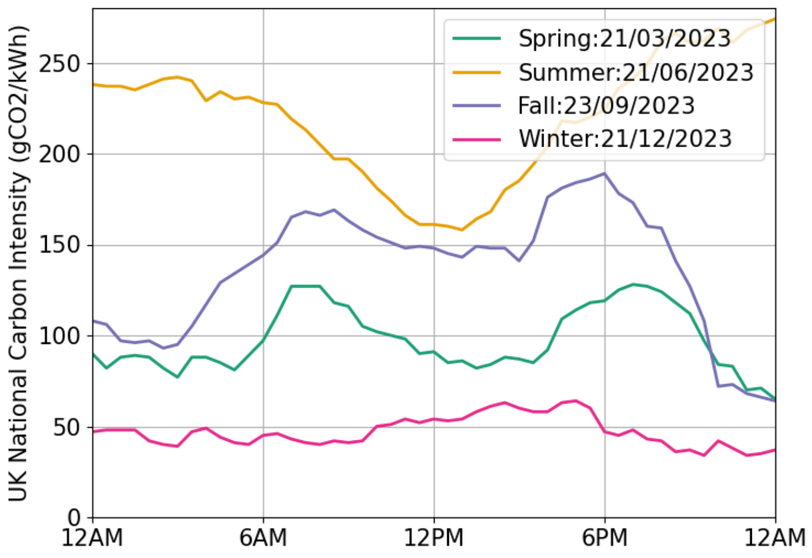
- Telecom, cloud and edge infrastructures consume increasing amounts of energy.
- Carbon emissions depend on both energy consumption and regional carbon intensity.
- The same workload can produce different emissions depending on where and when it is executed.
- Carbon-aware networking can support more sustainable digital infrastructure.



JOINER's distributed infrastructure enables carbon-aware deployment across multiple UK regions.

1.2 Carbon Intensity Over Time (Sample Day)

Regional carbon intensity varies significantly throughout the day as the electricity generation mix changes. This creates opportunities for carbon-aware workload scheduling and deployment



Example daily carbon intensity profiles.

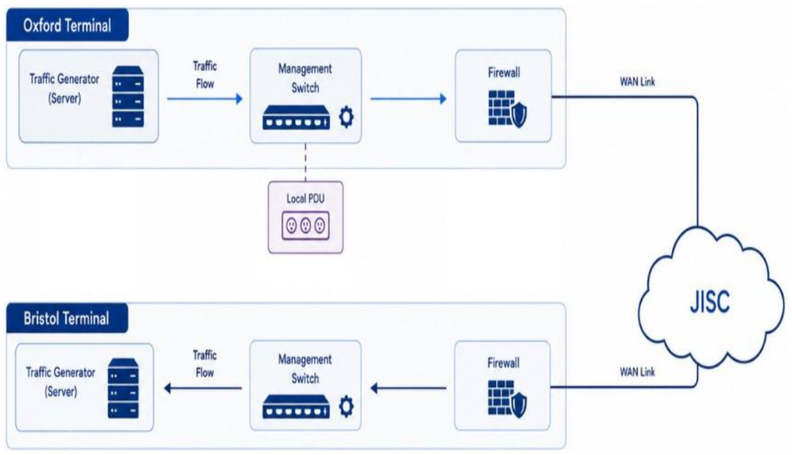
2. Research Objectives

1. Develop a carbon monitoring framework for distributed infrastructures.
2. Quantify both compute and network-related emissions.
3. Provide real-time and predictive carbon visibility.
4. Support carbon-aware deployment and optimisation decisions.

3. Methodology

3.1 JOINER Carbon Monitoring Testbed

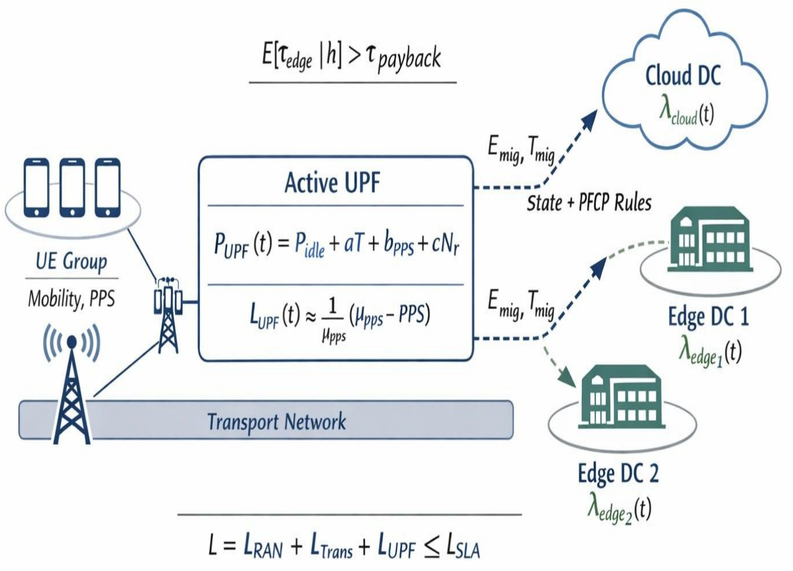
Distributed infrastructure used for carbon monitoring experiments.



JOINER carbon monitoring testbed.

3.2 Carbon-Aware UPF Migration Framework

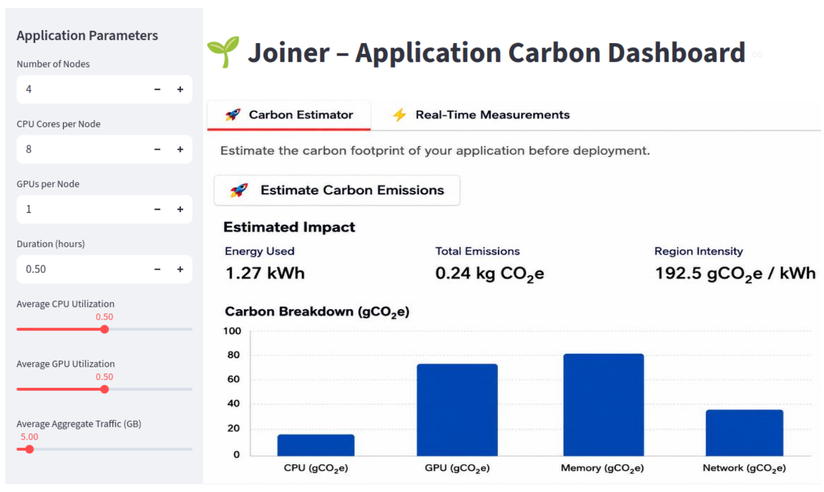
Carbon-aware UPF migration dynamically selects cloud and edge deployment locations based on carbon intensity, latency, and mobility.



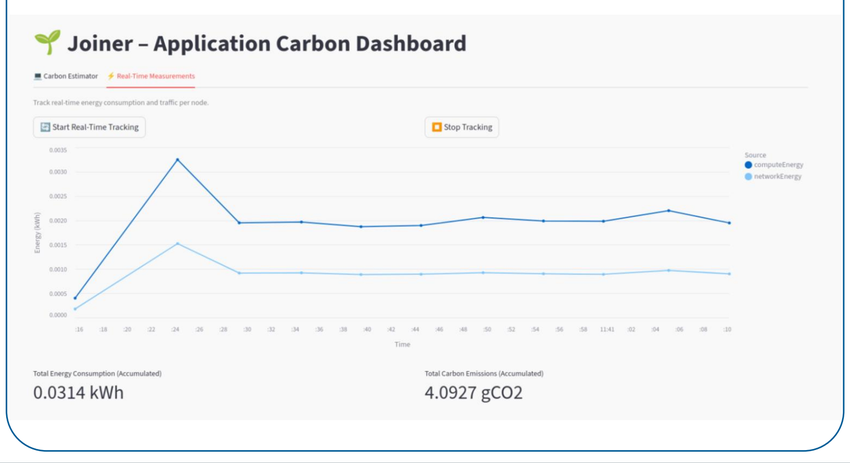
Carbon-aware UPF migration framework.

3.3 Carbon Estimation Interface (Offline Estimation)

The dashboard estimates an application's carbon footprint before deployment.



3.4 Real-Time Carbon Monitoring



4. Results & Findings

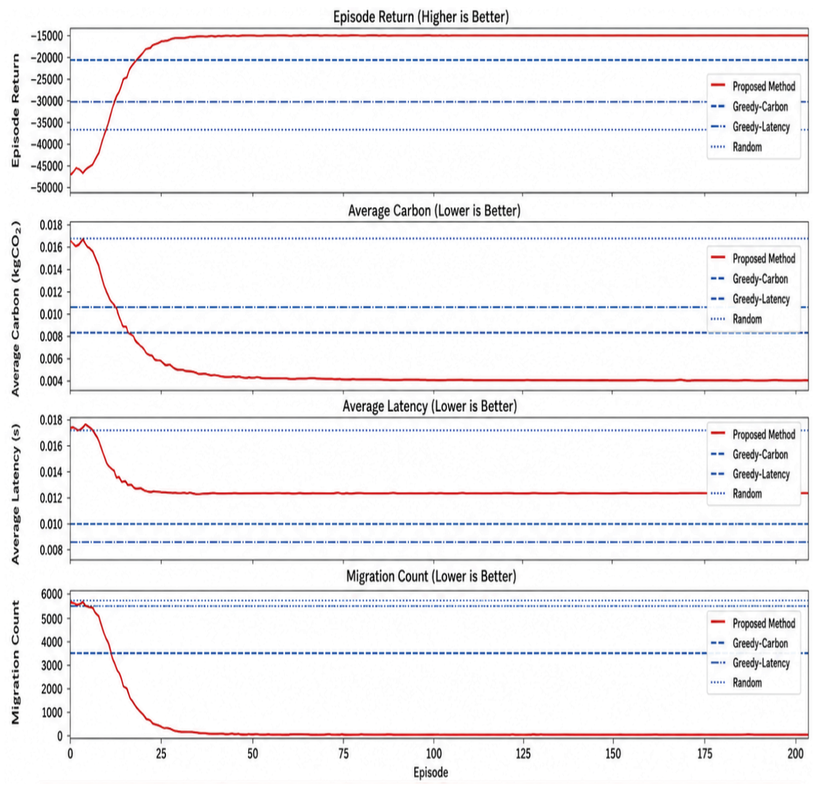
4.1 Deployment Overhead (Dashboard)

Location	Energy (kWh)	Emissions (gCO_2)
Oxford	0.1662	22.06
Glasgow	0.1652	21.93
Cambridge	0.1657	21.58

Key Observation: Dashboard deployment introduces negligible overhead (<2%) across all tested sites.

4.2 Carbon-Aware Optimisation Results

The proposed Reinforcement learning approach (in red) rapidly converges and achieves the best balance between carbon reduction, latency performance, and migration stability.



5. Impact/ Key outcomes

- Carbon emissions are significantly reduced compared to baseline approaches.
- Carbon-aware optimisation balances emissions, latency, and migration costs.
- Dashboard enables carbon monitoring and estimation for all JOINER users.

6. Conclusion

- EcoNGN demonstrates the feasibility of end-to-end carbon-aware telecom infrastructures.
- Carbon monitoring and optimisation can be integrated with minimal operational impact.
- The framework supports the transition towards more sustainable future networks.

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