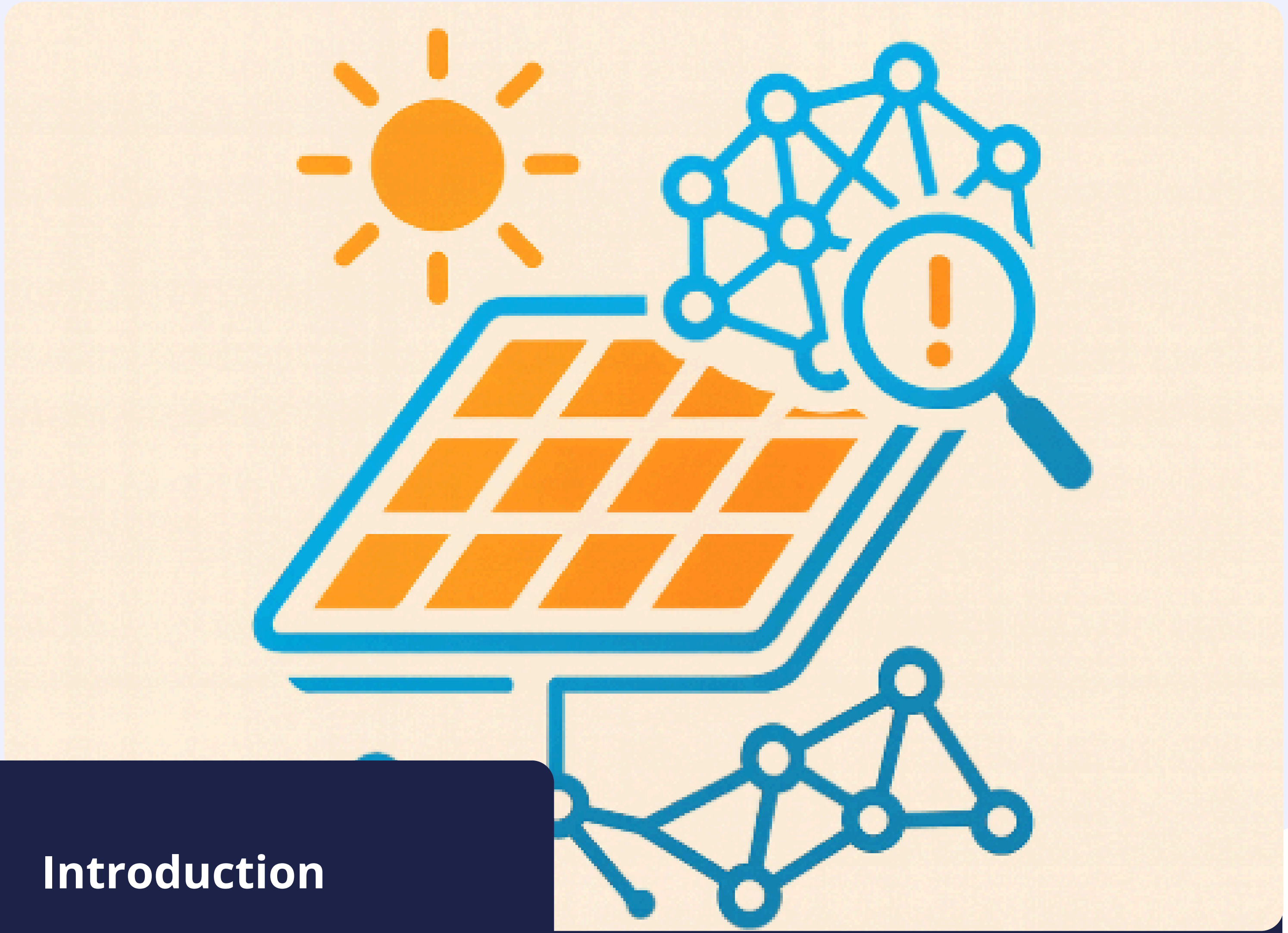
KIIT University

SolarMesh - ML-Based Anomaly Detection in Solar-Powered Rural Mesh Networks



Introduction

Rural mesh networks powered by solar energy play a vital role in connecting underserved communities, yet they often suffer from disruptions caused by battery drain, traffic congestion, and adverse weather conditions. To address these challenges, SolarMesh applies machine learning techniques to detect and diagnose anomalies, offering a proactive solution that enhances reliability and ensures more stable telecom connectivity in rural regions.

Objectives

- Simulate realistic mesh network behavior using synthetic time-series data.
- Detect anomalies using rule-based and ML models.
- Visualize network health and failure patterns for actionable insights.

Question

How can machine learning be used to detect and explain anomalies in solar-powered rural mesh networks to improve reliability and uptime?

Methodology

Network Simulation:
Created a mesh graph of 25–50 nodes with attributes like battery, traffic, status, and weather.

Time Series Data:
Generated one-day minute-level logs per node to capture dynamic network behavior.

Anomaly Types:
Defined battery outages, traffic congestion, and weather-induced link failures as key anomalies.

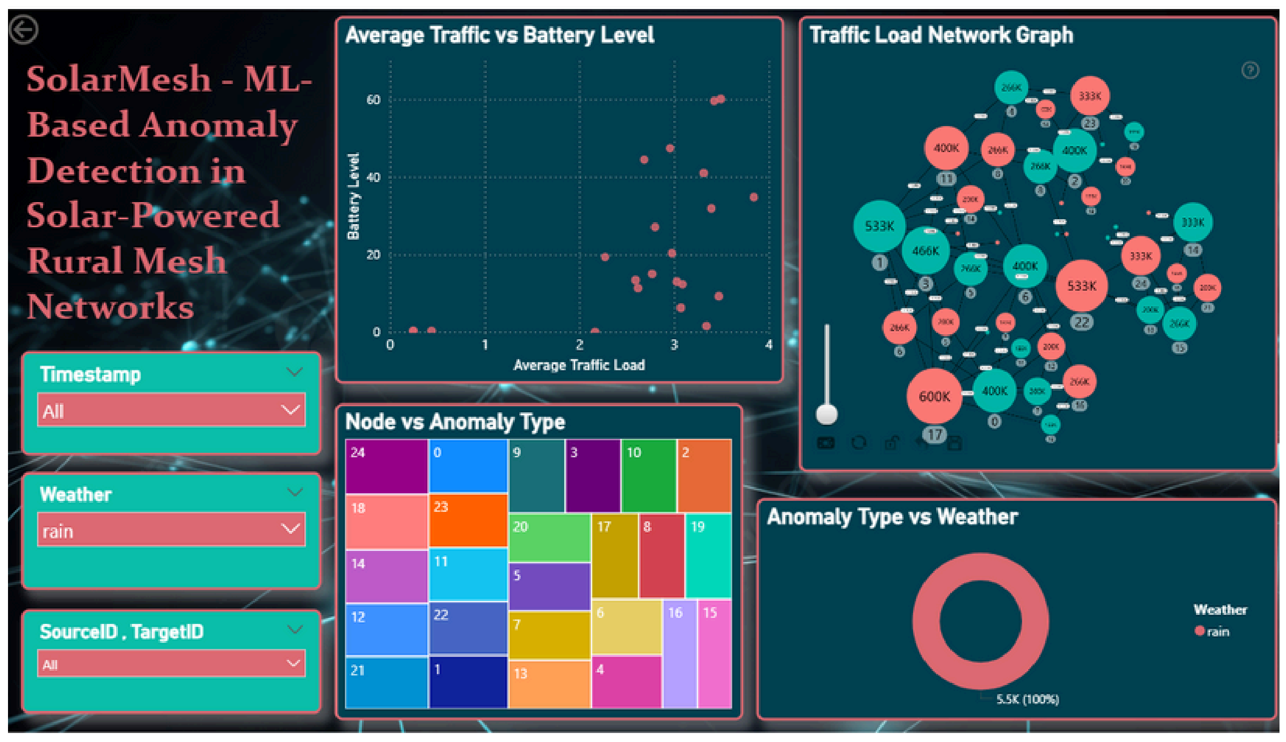
Detection Models:
Applied rule-based thresholds, Isolation Forest (unsupervised), and Random Forest (supervised).

Evaluation:
Measured performance using Precision, Recall, and F1-score, comparing rule-based vs ML approaches.

Result & Discussion

Key Findings

- Isolation Forest detected 82% of anomalies with minimal false positives.
- Rolling features (battery mean, traffic std) improved model accuracy.
- Congestion and battery outages were most frequent.



Challenges Identified

- Simulating realistic solar charging and traffic patterns.
- Balancing detection sensitivity vs false alarms.
- Visualizing dynamic mesh behavior in static dashboards.

Future Scope

- Incorporate real solar panel and weather sensor data.
- Deploy explainable AI (SHAP/LIME) for anomaly transparency.
- Extend to 5G rural towers and mesh-based smart village networks.

Conclusion

SolarMesh demonstrates that ML-based anomaly detection can significantly enhance the reliability of solar-powered rural mesh networks. By identifying failures early, it supports uninterrupted connectivity for remote communities and strengthens digital infrastructure.

References

- Ribeiro (2022). Principles of Energy-Aware Network Design.
- C-DOT Rural Connectivity Reports (2023–2025).

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