FOGGRID: TRANSFORMING MICRO-GRID OPERATIONS VIA BLOCKCHAIN AND FOG COMPUTING IN SINGAPORE

PROJECT SUMMARY

Micro-grids are gaining traction from rising distributed generation. This demands novel solutions to regulate operations on and off-grid, as well as both energy and monetary transfers between participants in the micro-grids and main grid.

In this research, we aim to develop and validate an intelligent micro-grid management system to secure the competitiveness of Singapore's energy market. This is done by synergizing two emerging technologies: blockchain for Peer-to-Peer (P2P) solar power trading and fog computing for grid infrastructure management. As part of the research, we have developed FogChain, an integrative, cost-effective, and scalable Micro-Grid Operating System (MGOS), consisting of three technical service layers:

- A novel microgrid information infrastructure based on the fog-computing paradigm (i.e. intelligence on the edge),
- A blockchain-based microgrid service layer, providing smart contract and decentralized control capabilities for grid application development, and
- A microgrid application layer (i.e. P2P energy trading) over the blockchain-based grid service.

This MGOS would fundamentally transform how solar power is traded among participating electricity prosumers, leading to potentially new operational and business models.

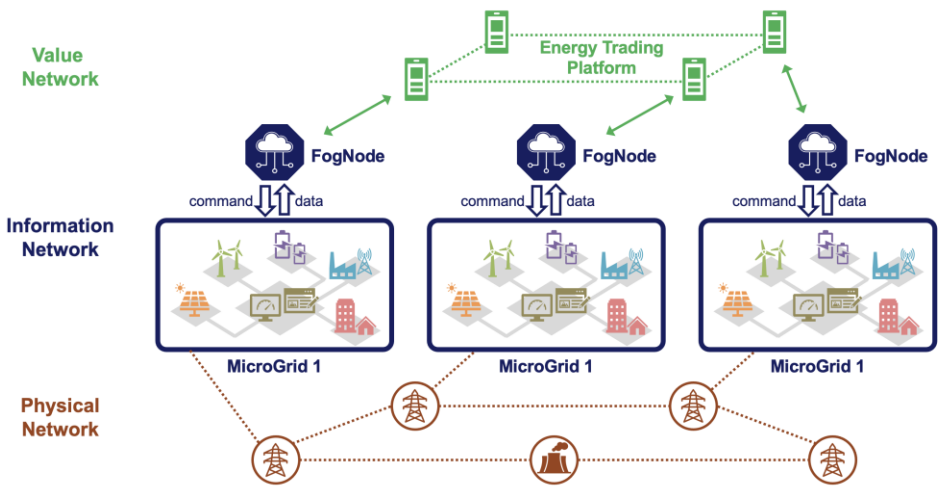

Figure 1. FogChain System Architecture.

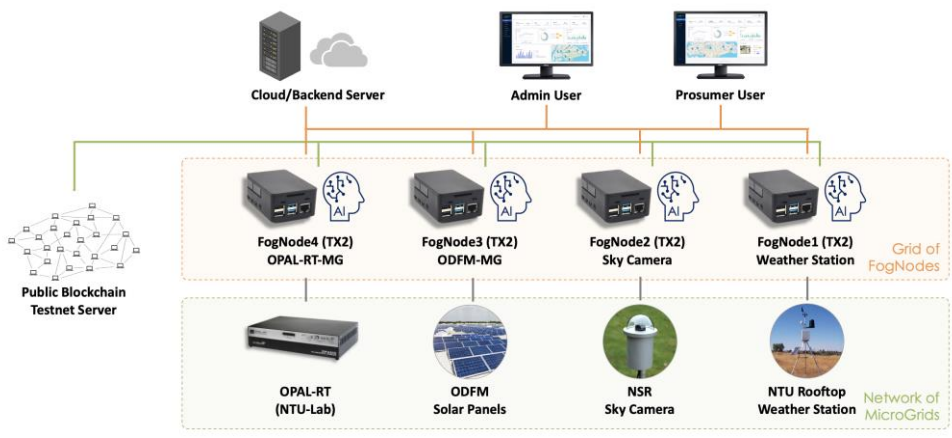

Figure 2. FogChain System Demo Setup.

PROJECT OUTCOMES

Key Developments

- As part of the FogChain system, a Fog Node was developed to process the data collected from the micro-grid and sensors, make energy trading decisions based on the market strategy and communicate with the trading platform for energy flow control. Relative to off-the-shelf hardware, the Fog Node demonstrates an **energy efficiency improvement of over 30% across all models.**

- A trustful smart contract-based double auction algorithm is developed for the energy trading, adopting a tamper-proof hash-based mechanism to enforce its integrity. A dual-coin ecosystem for the energy trading platform to address the volatility issue of crypto-currency has also been implemented. This **reduced blockchain trading latency to 15 seconds, lowering transmission cost of up to 20%**.

- To improve the robustness of solar yield prediction, we implemented a novel data imputation algorithm that can recover the missing time-series sensor data and reconstruct them by consolidating multi-modality data. An **accuracy of over 85% is achieved** for both short-term and long-term solar yield prediction.

- To facilitate the users to access the system and monitor the status of energy trading and the Fog Nodes, we have implemented an intuitive management web application with enhanced features, including the functional modules to manage trading, Fog Nodes, assets, blockchain platform, AI models, users, and system settings.

FogChain provides a promising solution for achieving efficient decentralized energy trading and intelligent distributed control for micro-grids. If deployed, the proposed solution is expected to provide an efficient smart grid management platform which could handle up to 126MW photovoltaic capacity in Singapore. In our future work, we will consider the security design of the FogChain system and deploy FogChain in a real-world micro-grid testbed for Proof of Value (PoV) trials.

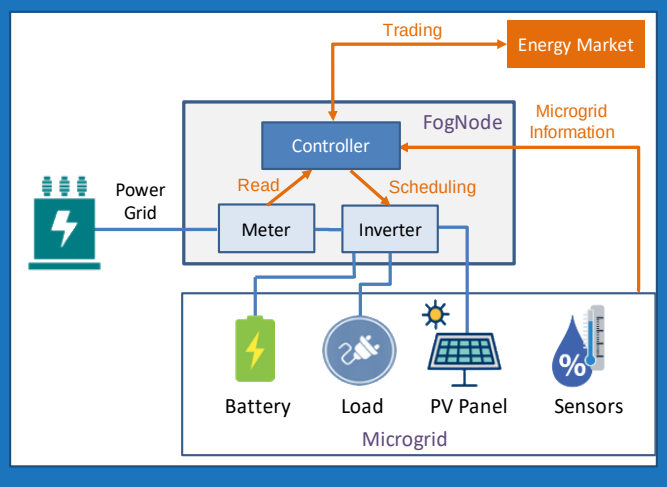

Figure 3. The control flows of Fog Node.

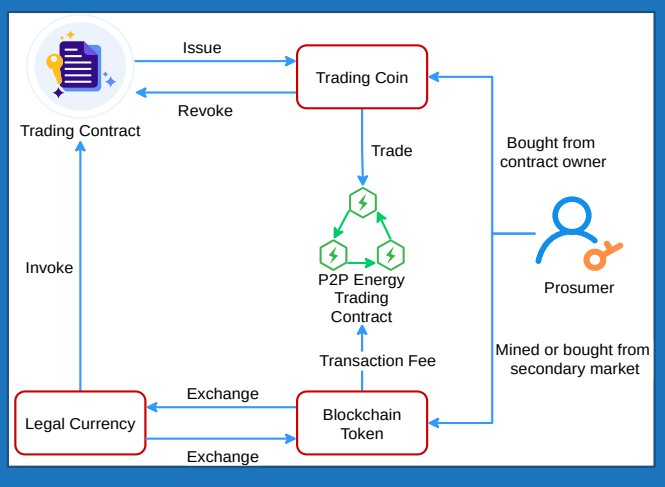

Figure 4. The relationship among legal currency, trading Coin, and blockchain token.

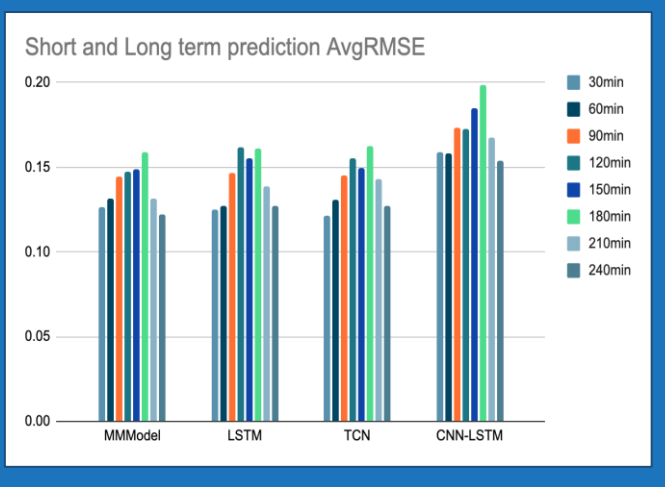

Figure 5. The solar yield prediction performance over different time horizons.

PRINCIPAL INVESTIGATOR

Yonggang Wen, Professor & IEEE Fellow

President's Chair, SCSE
Associate Dean (Research), CoE

PARTNERS

Sembcorp, Nvidia, IIC, EEA, EMA, NRF