White paper
Public

IoT Data Fabric and Analytics for Agile Trading of Distributed Energy Resources

Background

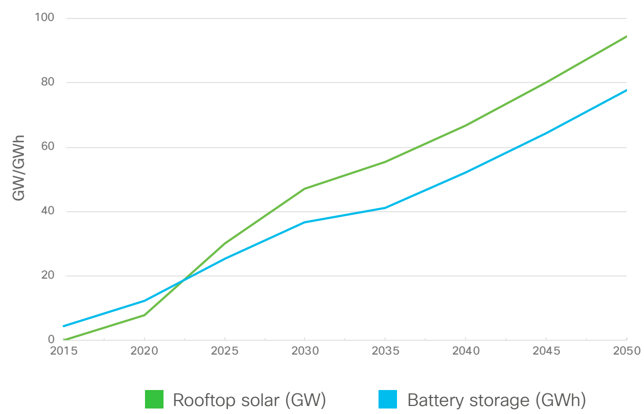
The energy sector is being challenged by a major push towards renewable energy and continuing demand for reliable and affordable electricity. With over a fifth of all homes already equipped with solar system, Australia is experiencing one of the world's highest uptake of home solar energy. By 2050 it is expected that almost half of all electricity generated in Australia will be delivered through Distributed Energy Resources, such as rooftop solar and household batteries.

The traditional centralised energy supply model is being disrupted by renewable energy sources that are geographically dispersed. While there are clear benefits for integrating DER assets into the grid, it also poses technical, regulatory and business model challenges.

Summary

We are at a unique crossroads in the energy sector where we are seeing a major push towards renewable energy and continuing demand for reliable and affordable electricity. Historically, utility companies generated power in one central location and then used the grid to deliver electricity to customers. However, over the past 10 years we have seen a rapid customer uptake of rooftop photovoltaic (PV) solar panels and it is expected that storage solutions (also referred to as Distributed Energy Resources – DERs) will follow similar trend. In 2018, the number of Australian households with rooftop solar passed 2 million - that's one in five.[1] Tomorrow's smart grid will be a constellation of many generation sources working together, shifting from the traditional one-way power flows from generation through grids to consumers to two-way flows including from the customers back into the grid. As we move towards decentralisation, there is an urgent need for new business models and the technology to support it. A new wave of innovative technologies such as Internet of Things (IoT), Edge and Fog computing, blockchain, machine learning, Artificial Intelligence (AI) will become key enablers for such a transformation.

Figure 1: Projected uptake of solar PV and battery storage, Australia 2015-2050[2]



A partnership between University of Technology of Sydney (UTS), Cisco and SAS was created to complete a trial where the feasibility and economic benefits of DER aggregation and a real-time energy brokerage in a residential framework were successfully designed, tested and verified. This trial focused on the operation and trading of PV solar panel energy through the concept of a DER aggregator.

An important aspect of this project was to design and test an energy brokerage model that is sustainable, accurate and fair to all involved parties. Real-time trading price and profit calculations were verified through the use of distributed architecture where the bulk of data processing and analytics took place at the edge of the communications network, effectively as close as possible to the DERs thus reducing latency and analytics by reducing reliance on a centralised data centre. Cisco's Kinetic IoT Data Fabric using Edge and Fog computing was used to process and aggregate data relating to generation and storage of energy from customer DERs. SAS Viva was used for analytics and visualisation.

The outcomes of this project show that by leveraging IoT, real-time distributed data and analytics we can enable DER trading thus reducing customer's cost and maintaining profit for aggregator/retailers. It also allows DER owners ("prosumers") to make smarter decisions on when to sell their DER for better profit, and with whom to trade. This model presents an opportunity to reduce overall cost and increase security of energy for Australia.

Introduction

The emergence of DER technology and the trend towards decentralisation, bring both opportunities and challenges. While customers with solar panels immediately benefit from an opportunity to reduce their power bills, they cannot trade their DER due to current constraints of the Australian National Energy Market (NEM). Market customers (i.e. transmission connected loads or retailers) or units generating below 30MW cannot operate directly in the market.[3] Integration of millions of DERs into the power system as an electricity resource provides an opportunity to improve demand response and potentially avoid or delay network investment. As DERs integrate into the grid, new business models and economic trading of the DER need to be considered.

In this project, solar PV DERs feed into the grid via a DER aggregator, that is responsible for managing and representing customer DERs in the energy market operations. DERs are managed indirectly through the use of price signals for energy consumption charges and remuneration for energy fed back into the grid.

Challenge

- Adoption of rooftop photovoltaic and battery storage solutions are increasing at a rapid rate, but the majority of these cannot be integrated into the National Energy Market hence not maximising for efficient trading
- Decentralisation and the involvement of new types of energy generation parties, calls for new business models and tools to be developed

Opportunity

- By aggregating a large number of small residential energy assets, there is an opportunity to more efficiently leverage an existing power supply
- Success depends on the ability to provide a fair and dynamic energy trading model for all involved parties

Outcome

- A real-time distributed IoT Data Fabric based approach coupled with distributed analytics models provides effective mechanism for distributed energy trading
- Computational analysis on the Edge reduces latency and enables dynamic and real-time energy trading models

Some of the considerations for managing small scale, distributed and dynamic DER are:

- Enablement of appropriate regulatory framework, infrastructure, as well as, compatible algorithms, software and analytic tool set;
- A need for a distributed and data driven trading structure and models for effective and agile way to aggregate DER participation in the electricity markets as a single coordinated entity;
- Smart household DER system which allows prosumers to make decisions on electricity usage in response to price signals or dispatch signals with sophisticated home energy management system as part of the smart home solution;
- A secure and trustworthy set of technology platforms that will be resistant to disruption or coercion by cyber attackers.

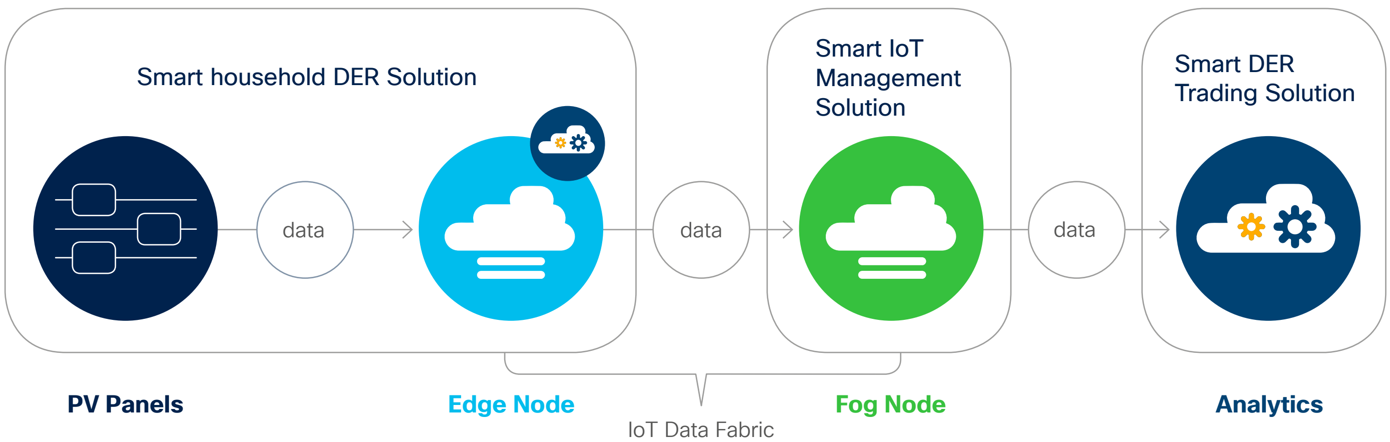
By creating a real-time model of supply and demand, trading prices and profits, DER aggregators can make on-the-fly decisions needed for DER operation and energy trading. The technology advancement in the IoT field through distributed intelligence and data fusion (Edge and Fog computing) allow us to achieve this. As part of this trial, we successfully designed and tested the dynamic trading structure by leveraging Cisco's Kinetic IoT Data Fabric combined with Edge and Fog computing for distributed real-time analytics and SAS ESP and Viya for streaming data processing and analytics as shown in Figure 2.

The IoT Data Fabric is a highly distributed virtual layer responsible for managing flow of data. Edge and Fog computing brings the applications and analytics to the edge allowing data to be processed as close as possible to the data source, which is crucial for supporting many real-time applications that further optimise the distribution, bidding and dispatch processes. This model supports a rapid, agile decision capability at the edge of the network and centralised approach for data modelling, taking into consideration broader range of data such as current energy demand, generation and historical data.

As part of this project we've set out to address some of the broader questions:

- Firstly, what operational and regulatory changes are required in the electricity market to support wide range of current and future energy generation sources.
- Secondly, determine whether technology such as IoT and real-time distributed data and analytics can support a sustainable energy brokerage model.
- Thirdly, given the importance of the viability of electricity services business models, we need to consider what business models can support future smart grid solutions.

Figure 2: Distributed Data Driven Architecture for Trading DER



Methodology

General framework

Current electrical distribution networks are not designed to handle highly distributed energy resources. Decentralisation and integration of DERs into the grid is a mammoth task and requires review of regulatory frameworks, standards, business models and overall network design. One thing is certain that the amount of data generated will increase dramatically and grid edge innovation is paramount. It is foreseen that some form of aggregation function for management and operation of DERs will come into play. The aggregator at this level is well positioned to provide forecasting, scheduling, dispatch and other functions within its geographic area of control. Data aggregation and processing closer to the DERs will help reduce latency, and provide timely insights.

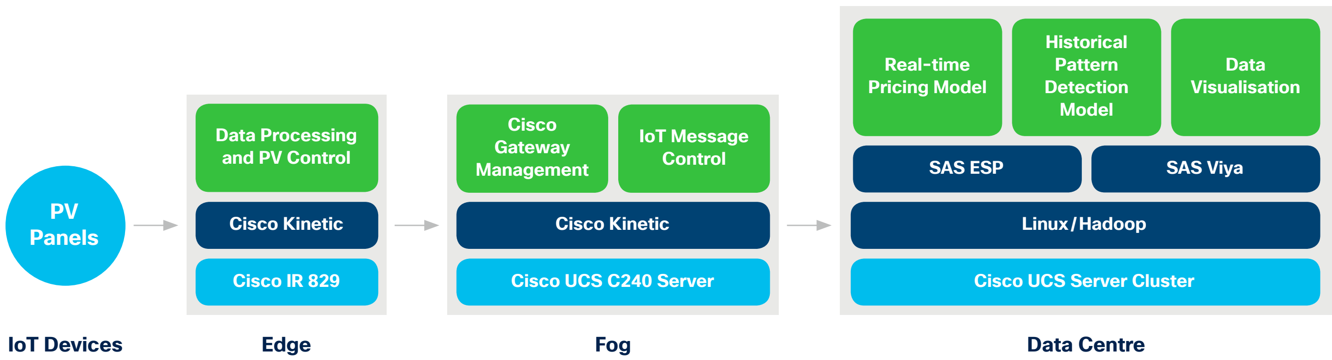
Pilot setup

For this pilot, we designed and implemented an IoT Data Fabric and Analytics based DER Trading system to support agile trading of DER. As shown in Figure 3, the DER Trading system consists of four key parts: the PV storage systems, edge router, database and visualisation at the data centre. The test environment was setup at UTS and includes the following components:

- Solar PV panels and battery
- Cisco IR829 Industrial Integrated Service Router (ISR)– edge router enabling data processing and applications to run close to the source of data
- Cisco's Kinetic – IoT Data Fabric is a distributed virtual layer responsible for data extraction, conversion, compute and managing the flow of data from devices
- Cisco UCS servers – provide compute and storage in the data centre and Fog locations
- SAS Event Streaming Processing (ESP) software – provides analytics capability
- SAS Viya visual statistics and visualisation tool set at both the edge and the data centre

The edge nodes are viewed as devices installed and connected to the solar PV panel and the battery, providing small-scale embedded local compute resources for the sensor/device as well as last-mile network connectivity. The fog node provides larger scale Edge computing capability across aggregated groups of edge nodes. The solution is designed to run decision making models at the edge to reduce latency and enable real-time decision making process, and run the trading model at the data centre where broader range of data sets are considered as part of the trading model. Cisco Kinetic, running on the edge router IR829, receives the solar energy data, and provides near real-time edge processing and analysis of data, immediately forwarding critical data and events to the aggregator, and also forwarding aggregated historical data to the data centre where SAS ESP and SAS Viva analytics tools reside. The data centre fulfils its traditional role of housing the data and providing the tools to analyse and use the data. The big data analysis needs at the data centre are supported by SAS Visual Analytics (VA) and SAS Visual Statistics (VS).

Figure 3: Technical Architecture – DER Trading System



In the first instance, a baseline was created for current energy generation and efficiency of the DER by analysing how much energy has been produced by the DER as a function of time, weather, and how much is in the storage, and the efficiency of the energy generated by the DER in terms of matching the energy needs, and the potential value that it can bring through sharing and trading. In the second phase, focus shifted to building a largescale simulation of a residential microgrid and the brokerage of energy. This includes estimating economically viable scale of the number of DERs required for energy brokering, and evaluating effectiveness of the proposed solution framework.

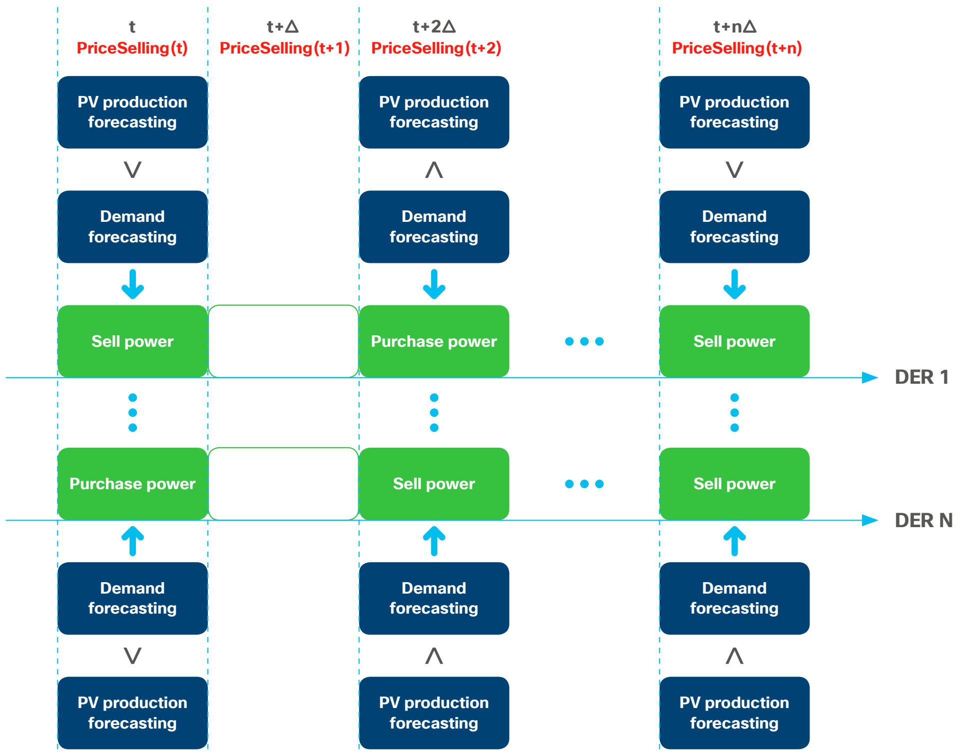
Trading models

One of the key research focus areas for this trial was exploring trading models and identifying one that is considered fair to all parties.

The *trading model* described here is used to determine the price for each time interval (=30 minutes) for trading DERs between an aggregator and a prosumer.

Suppose an aggregator has N prosumers signed in, denoted as DER1 to DERn, respectively and in each time interval, the total aggregated PV production is not greater than the total demand or consumption within the jurisdiction of an aggregator. At midnight of each day, the aggregator runs forecasting modules to predict the PV production and demand in each time interval in the next day for each prosumer site and determine the amounts of electricity that needs to be purchased from the main grid in the wholesale market. Next day, dispatch instructions are executed and the aggregator incur the cost for purchasing electricity from the wholesale market at spot market price and also the cost for paying prosumers who fed their surplus DER into the local grid at the DER trading price. The revenue of the aggregator is the return from selling electricity to customers or prosumers who do not have enough PV production. The trading model is used to determine the DER trading price for each time interval based on the DERs and the power consumption at each prosumer site, as illustrated in Fig. 4. DER trading price in each time interval depends on the PV production and power consumption from all prosumers.

Figure 4: DER trading price at each time interval depending on prosumers' sell/buy status



The trading model is designed to determine at what price the aggregator purchase power from prosumers in each time interval. This price value mainly depends on the feed-in and purchased amount of electricity of all prosumers. The feed-in amount is the electricity supply to other customers/prosumers in the local distribution network, and the purchased amount is the demand which can be from the grid or from other prosumers. Before calculating this DER selling price, the model needs the historical power market spot prices to determine a reasonable range for the DER selling prices.

Benefits of a residential prosumer using the trading model

With the DER trading price, the prosumer power cost is calculated based on the difference between the cost of purchased electricity and gain from selling the feed-in electricity to the aggregator/retailer.

The power cost reduction for each prosumer can be determined by the difference between the power cost incurred before adopting this model using the current feed-in tariff and the one after adapting this model (using the DER trading price).

Benefits of aggregator from using the trading model

The aggregator benefit can be calculated from the difference between aggregator profits before and after using the trading model. The aggregator profit is computed by subtracting the cost of aggregator from its revenue. The aggregator's revenue is determined by the electricity price and amounts that aggregator sells to customers. The aggregator's cost consists of two parts: one is the cost to buy electricity from prosumers which can be computed in the same way for both cases of using trading model and not using trading model except for the prices used. The other part is the cost to buy electricity from the main grid.

Conclusion

It is generally accepted within the industry that the future of the energy sector will include diverse, highly distributed renewable energy generation sources. Work has already commenced to review technical standards, regulatory and market constructs to enable this integration.

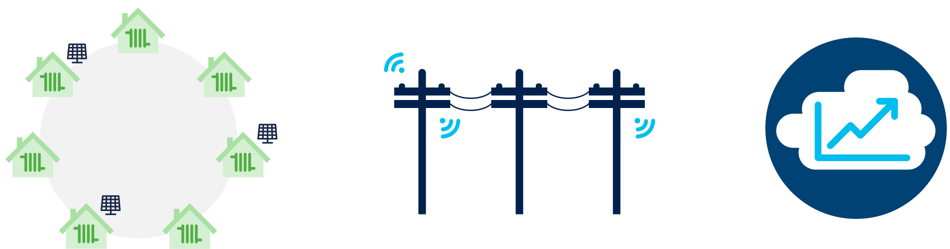
This project confirmed that energy trading of generation assets below 30MWh is feasible and presents a tangible opportunity to both supply and demand. We have verified the operation and trading of the PV solar panel energy via an aggregator. We further designed and developed the stream data processing models to calculate trading prices and profits in real-time so that aggregator and prosumers can make on-the-fly trading decisions. To encourage more consumer and aggregator participation, we believe an accurate and fair trading model is required.

During this project a distributed architecture was used to verify the microgrid scenario where energy trading is limited to a community and facilitated by an aggregator. However, this architecture and principles described here can be further extended to support scenarios where surplus energy is fed back into the grid and/or active DERs controlled remotely. While centralised data modelling allows for historical data, weather information, overall demand/supply and other data to be taken into consideration, analytics and computational capability on the edge makes it possible to dynamically adjust trading model to reflect real-time conditions thus making the trading model more accurate and attractive.

In addition, Edge and Fog computing has the potential to improve the speed and efficiency to manage distributed energy resources especially where low bandwidth communications are in operation and bandwidth is scarce.

It was concluded that a distributed IoT Data Fabric with analytics was essential in order to provide an accurate reflection of demand and supply in real-time. The integration of SAS analytics combined with Cisco Edge/Fog computing enabled decisions to be automated in an efficient and cost effective manner.

Finally, architecture verified as part of this trial provides a solid foundation for other use-cases:



	Edge Function	Fog Function	Cloud Function
Microgrid Energy Trading within Community	· Data collected from Smart Meters, Batteries and Solar Panels · System Control for Solar, Battery Chargers etc	· Data Aggregation · Trading Models and Ledger	· Trading Oversight and System Control · Integration with NEM
DER Integration & Large Scale Energy Trading	· System Input – Solar Harvest, Battery Charge Level · System Output – Appliance Control, User Feedback, Invertor Control	· DER Data Aggregation and Logic · Trading Models	· Centralised Trading Models · Integration with DNSP · Integration with NEM
Demand / Response	· Automatic Appliance Control · Pattern Usage Analysis · System Output – Appliance Control, User Feedback, Invertor Control	· Data Aggregation · Data Consolidation	· Centralised Analysis of Demand & Supply · Integration with DNSP

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