Optimal Composition of Prosumer Aggregations

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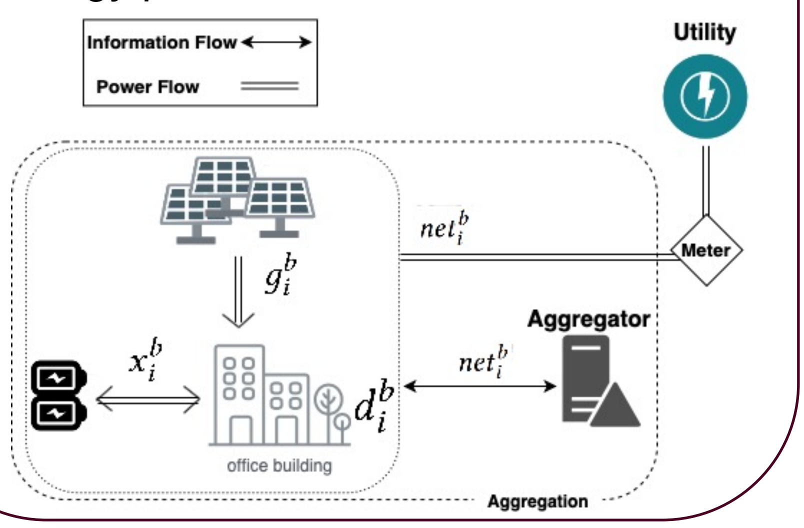
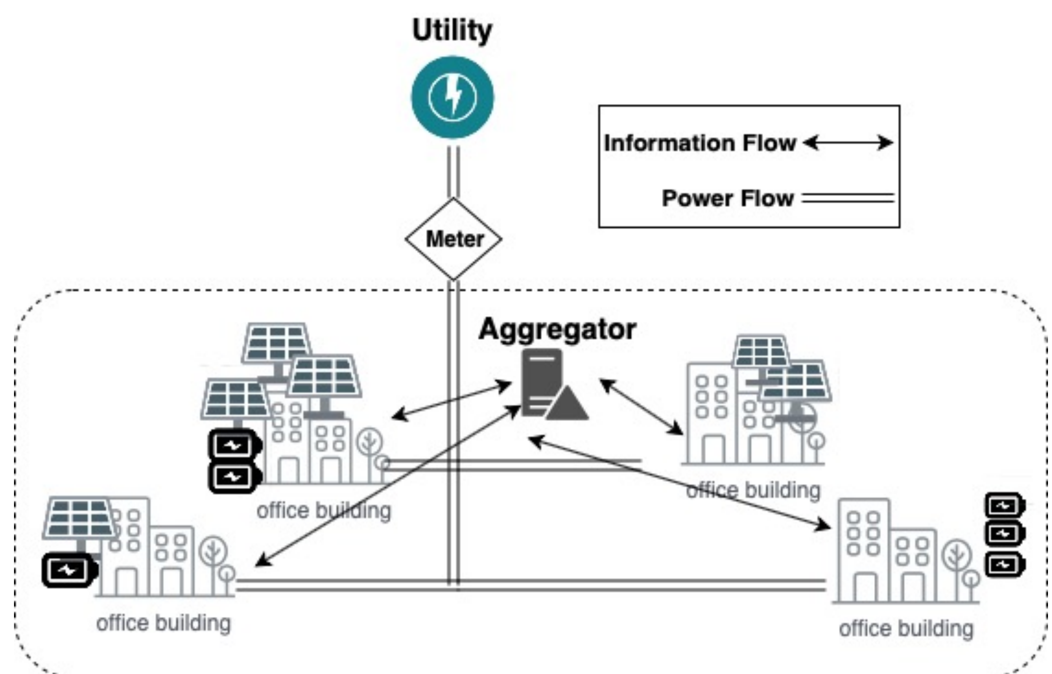
A **prosumer** is an entity which can both **produce** and **consume** energy. Typically, prosumers are cost-sensitive and modify their net energy consumption in response to energy prices.



Utilities sell energy at a higher price than the price at which they buy back surplus generation from retail customers. Aggregations can profit off this price differential.

Aggregations can make use of **social net-metering schemes**, where the prosumer participants trade energy with each other first, and then present the net demand to the utility as a single entity.



Research question: *Which prosumers would form the optimal aggregation, i.e., an aggregation that benefits the participants the most?*

Model: The prosumer acts in a manner which minimizes its costs.

$$\min_{\mathbf{u}} J_P(\boldsymbol{\pi}_b,\boldsymbol{\pi}_s)=\sum_{t=1}^{T}\left[\pi_b^{(t)} z_+^{(t)}+\pi_s^{(t)} z_-^{(t)}+\pi_{\text{bat}}|u^{(t)}|\right]$$
$$=\boldsymbol{\pi}_b^\top \mathbf{z}_+ + \boldsymbol{\pi}_s^\top \mathbf{z}_- + \pi_{\text{bat}}\mathbf{1}^\top|\mathbf{u}|$$
$$\text{s.t.} \quad 0\le L\mathbf{u}\le c$$

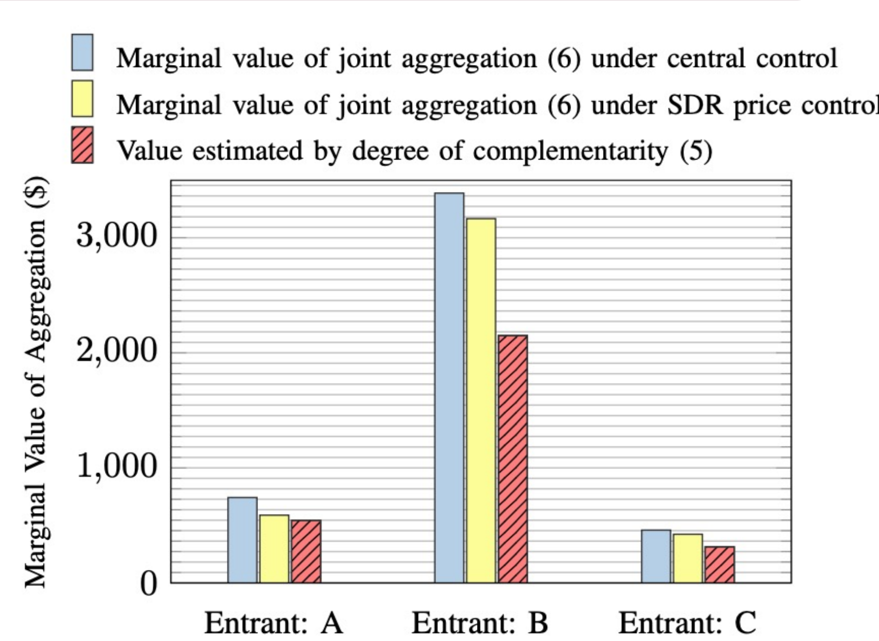
Model: Aggregations can be centrally controlled or use market mechanisms (like price) to reflect the trading balance. We focus on a centrally controlled aggregation, which also achieves the minimum possible social cost.

$$\min_{\mathbf{u}_i, i\in S} J_S=\boldsymbol{\pi}_b^\top\Big(\sum_{i\in S}\mathbf{z}_i\Big)_+ + \boldsymbol{\pi}_s^\top\Big(\sum_{i\in S}\mathbf{z}_i\Big)_- + \pi_{\text{bat}}\mathbf{1}^\top\Big|\sum_{i\in S}\mathbf{u}_i\Big|$$
$$\text{s.t.} \quad \mathbf{0}\le L\mathbf{u}_i\le c_i\mathbf{1}\ \forall i\in S$$

Result 1. *In order to maximize social welfare, an aggregation should preferentially add a participant k that maximizes the **degree of complementarity** to the existing participants S, i.e. has an optimally complementary consumption curve. A lower bound on the degree of complementarity can be calculated as*

$$\frac{\boldsymbol{\pi}_b^\top - \boldsymbol{\pi}_s^\top}{2}\left(\left|\sum_{i\in S}\mathbf{z}_i^*\right| + |\mathbf{z}_k^*| - \left|\sum_{i\in S}\mathbf{z}_i^* + \mathbf{z}_k^*\right|\right) \qquad (5)$$

where $\mathbf{z}_i^*, \mathbf{z}_k^*$ are the optimal consumption curves for prosumers in the existing aggregation S and the new entrant k respectively.



This result can be used to analyze potential members for a prosumer aggregation and build an aggregation that achieves the highest social benefit. A profit seeking entity like a commercial DER aggregator can use this result to guarantee a minimum profit margin.

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