Distributed Cross-Community Collaboration for the Cloud-Based Energy Management Service

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Abstract

Customers' participation is a critical factor for integrating the distributed energy resources via demand response and demand-side management programs, especially when customers become prosumers. Incentives need to be delivered by the energy management service to attract prosumers to operate their distributed energy resources and electricity loads grid-friendly actively. The cloud-based energy management service enables virtual trading for customers within the same community to minimize cost and smooth the fluctuation. With the potential fast-growing number of service providers and customers, the needs exist for efficiently collaborating across multiple service providers and customers. This work proposes the distributed cross community collaboration (XCC) for the cloud-based energy management service to enable collaboration across multiple communities and service providers. The XCC can efficiently handle large-scale variables and data with various allocated computing resources and is formulated as an alternating direction method of multipliers optimization problem. This work also introduces a cross-community adjustment to avoid the overwhelmed exchanged data and computations among multiple communities under uncertainty. Performances are evaluated in experiments with the discussions.

Framework

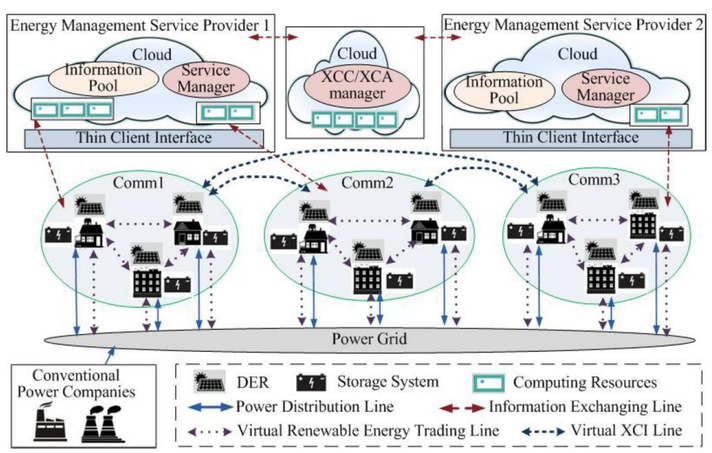


Fig. 1. Framework for the energy management service with XCC and XCA

Reference

The work presented in this poster is from paper: Y. -W. Chen and J. M. Chang, "Distributed Cross-Community Collaboration for the Cloud-Based Energy Management Service," 2021 5th International Conference on Smart Grid and Smart Cities (ICSGSC), 2021, pp. 160-168, doi: 10.1109/ICSGSC52434.2021.9490415.

What is proposed in this work

Distributed Cross-Community Collaboration (XCC) for the Cloud-Based Energy Management Service

- Deliver incentives to customers within all the cooperated communities and various service providers.
- Formulated as the multi-blocks Alternating direction method of multipliers (ADMM) model
  - efficiently handle the large-scale data and variables with various allocated computing resources.
- Introduced the cross-community adjustment (XCA)
  - to avoid the overwhelmed exchanged data and computations among multiple communities under uncertainty.

Model for Cross-community Collaboration (XCC)

For the simplification, the discussed number of multiple communities is set to three (Comm1, Comm2, Comm3)

TABLE I. Presentation of z for 3 involved communities

Variables	Interaction behaviors	Constrains
z^1	*comm1* buy from *comm2*; *comm2* sell to *comm1*	$\leq l_1$
z^2	*comm1* buy from *comm3* *comm3* sell to *comm1*	$\leq l_2$
z^3	*comm2* buy from *comm1* *comm1* sell to *comm2*	$\leq l_1$
z^4	*comm2* buy from *comm3* *comm3* sell to *comm2*	$\leq l_3$
z^5	*comm3* buy from *comm1* *comm1* sell to *comm3*	$\leq l_2$
z^6	*comm3* buy from *comm2* *comm2* sell to *comm3*	$\leq l_3$

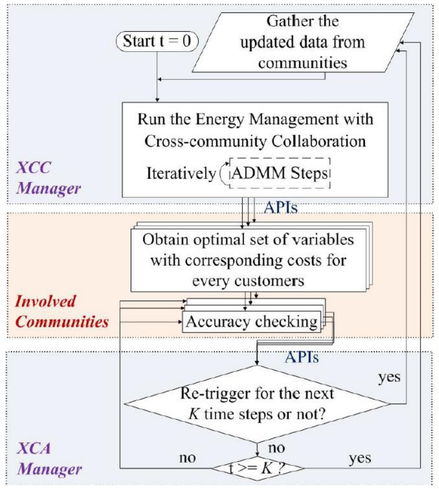


Fig. 2. Collaborative Procedure with XCC and XCA

Objective Function:

Minimize the cost via the trading among communities

$$g(\boldsymbol{z}) = (P^s_{comm2} - P^b_{comm1})z^1 + (P^s_{comm3} - P^b_{comm1})z^2 + (P^s_{comm1} - P^b_{comm2})z^3 + (P^s_{comm3} - P^b_{comm2})z^4 + (P^s_{comm1} - P^b_{comm3})z^5 + (P^s_{comm2} - P^b_{comm3})z^6 \quad (28)$$

Subject to:

$$\boldsymbol{Ax} \geq \boldsymbol{Dz} \quad (29)$$

$$\mathbb{1}\boldsymbol{z} \leq \boldsymbol{l} \quad (30)$$

Formulation

Centralized problem

$$\min_{\boldsymbol{x}_m, \boldsymbol{z}} \sum_{m \in \mathbb{O}} f_m(\boldsymbol{x}_m) + g(\boldsymbol{z})$$

subject to: (30), and

$$\boldsymbol{A}_m \boldsymbol{x}_m \geq \boldsymbol{D}_m \boldsymbol{z}, \forall m \in \mathbb{O}$$
$$\boldsymbol{P}^{ieq}_m \boldsymbol{x}_m \geq \boldsymbol{b}_m \quad, \forall m \in \mathbb{O}$$
$$\boldsymbol{P}^{eq}_m \boldsymbol{x}_m = \boldsymbol{beq}_m, \forall m \in \mathbb{O}$$

Distributed multi-block ADMM problem

$$\min_{\boldsymbol{X}_m, \boldsymbol{Y}_m, \boldsymbol{\phi}} \sum_{m \in \mathbb{O}} \theta(\boldsymbol{X}_m)$$

subject to:

$$\boldsymbol{A}_m \boldsymbol{X}_m - \boldsymbol{Y}_m = \boldsymbol{0} \quad, \forall m \in \mathbb{O}$$
$$\boldsymbol{B}_m \boldsymbol{X}_m - \boldsymbol{C}_m \boldsymbol{\phi} = \boldsymbol{0}, \forall m \in \mathbb{O}$$
$$\boldsymbol{G}\boldsymbol{c}^{ieq}_m \boldsymbol{X}_m \geq \boldsymbol{G}\boldsymbol{b}_m \quad, \forall m \in \mathbb{O}$$
$$\boldsymbol{G}\boldsymbol{c}^{eq}_m \boldsymbol{X}_m \geq \boldsymbol{G}\boldsymbol{beq}_m \quad, \forall m \in \mathbb{O}$$

Experiments and Results

- The XCC for the cloud-based energy management service achieves a more significant advantage when the ratio of *l* to the number of customers within each community is larger.

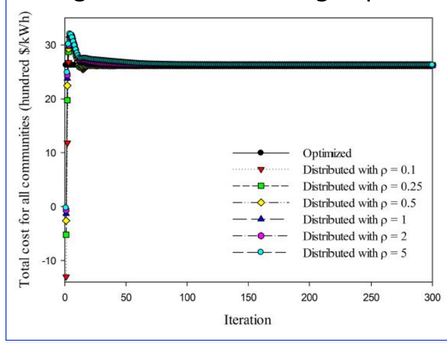
Case without XCC

	low DER production capacity			high DER production capacity		
Customers	25	50	75	25	50	75
l = 0	2062.2	4867.2	7172.1	1467.0	3461.0	5237.4
l = 500	1654.0	4398.8	6651.5	1017.2	2894.2	4621.9
l = 1000	1387.5	4062.3	6267.9	685.33	2491.7	4142.7
l = 1500	1208.7	3750.4	5936.8	391.42	2144.5	3748.5

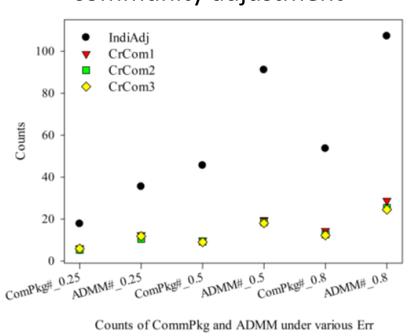
- With the storage system involved in energy management, the cost-saving can be further reduced.

	low DER production capacity				high DER production capacity			
l	0	500	1000	1500	0	500	1000	1500
no storage	2079.0	1683.1	1426.0	1255.5	1489.7	1054.1	723.92	440.09
with storage	2062.2	1654.0	1387.5	1208.7	1467.0	1017.2	685.33	391.42

- The problem successfully converges regardless of the setting of ρ.



- Advantage of cross-community adjustment



Conclusion

The cross-community collaboration (XCC) is proposed for the cloud-based energy management service in this work. With the enabled cross-community collaboration among the involved communities, the energy management service can deliver an incentive to engage customers by minimizing global costs (including environmental cost and electricity cost). The proposed XCC also shows the potential for engaging customers without a storage system to the energy management service. The cloud-based energy management service with the XCC is formulated as the distributed multi-block ADMM problem to practically and efficiently handle the massive data and variables with various allocated cloud computing resources. The communication time for the distributed XCC is small as different cloud computing resources utilize it from different energy management service providers at the intercloud or the intra-cloud level. The cross-community adjustment (XCA) is proposed to enhance the efficiency of XCC under uncertainty by reducing the unnecessarily overwhelmed data exchanging and computations.