A Markov Chain Monte Carlo based Admission Control Mechanism for Multiple Parking Stations

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Abstract

With the significant increase of EVs, parking lots recently become parking stations where car owners can charge their car during the parking time. Charging capacity of each parking station depend on global peak demand of micro-grid. To ensure that charging demand in different parking stations is less than this global peak demand, central aggregator located at micro-grid is utilized to control charging of EVs' battery at all parking stations. An efficient admission control mechanism is designed at central aggregator to how it can maximize benefits for utility provider while guarantee of satisfying the global peak constraint.

In this study, an efficient admission control mechanism is constructed based on Marko Chain Monte Carlo. The simulation results illustrate that proposed algorithm has a close proximity result to optimal algorithm in both total revenue and number of served EVs. In addition, proposed algorithm outperforms compared to greedy algorithm under various simulation scenarios.

Key word: Electric vehicle, parking station, admission control mechanism, MCMC.

1. Introduction

In the recent years, electric vehicles (EVs) have received wide interests from both commercial and research communities. EVs are considered as a key technology for achieving efficient transportation with high fuel economy and low pollution emissions [1]. However, EVs are not attractive more car drivers to switch from traditional vehicle to EVs. One reasons for this is due to EVs have a limited driving distance [2], then EVs require significant amount of time to be recharged. Parking lots recently is not only where to park cars but also where EVs owners can recharge their car. Parking lots equipped charging points is known as parking stations [1]. With this model, EVs owners can charge their EVs during the period parking.

In particular, multiple parking stations are governed by a single-owner micro-grid known as utility provider, e.g., university or town [1, 3]. In this situation, service capacity of each parking station depend on not only their ability such as number of variable parking spaces, electricity supply but also global peak demand of micro-grid. Central aggregator located at micro-grid is utilized to control charging of EVs' battery at all parking stations [3]. To manage EVs charging requests, two important problems that need to be solved are admission control and scheduling shown as in Fig. 1. In this study, we focus on how to design an efficient admission control then it can determine the set of EVs that will maximize benefits for utility provider such as satisfying the global peak constraint.

In this paper we present an admission control mechanism for EVs having charging requirement during parking time. The problem is illustrated as Knapsack problem. It is NP-hard problem, then we propose an algorithm based on Markov Chain Monte Carlo to achieve admission control mechanism efficiently.

The remainder of this paper is organized as follows. The full sketch of admission control mechanism is analyzed in Section 2. In section 3 we show our simulation results. Section 5 summarizes the paper and draw some future works.

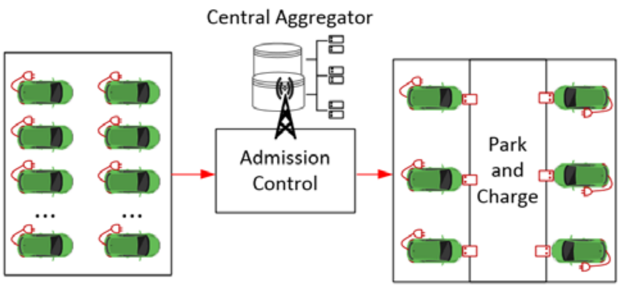

Figure 1: System model

2. System model

In this study we consider a model system illustrated in Fig.1 composed of two type of entities: parking lots capable of charging EVs and EV themselves. All parking stations are managed by a single utility provider. A global peak demand constraint is determined by the micro grid owner such as the aggregate charging demand in different parking stations is less than this global peak demand. The primary objective is trying to maximize the total revenue of utility provider.

In admission control module, an admission control mechanism is designed to find a best set of EVs charged that maximize the total revenue of parking lot.

There are n EVs $\mathcal{E}=\{e_1,e_2,...,e_n\}$ requiring charge service. The required charge amount of each EV i is ω_i. Parking station charges v_i for each EV i. The amount of v_i is determined as

$$v_i=\eta*\omega_i,\ \ \forall i\in\mathcal{E} \qquad (1)$$

Where η is electricity selling price.

2.1. Problem formulation

The goal of this section is to formulate an optimization of maximizing the total revenue of parking stations while respecting global peak constraint. This main objective can be described mathematically by a binary decision values as

$$x_i = \begin{cases} 1 & \text{If charge request of EV } i \text{ is accepted.} \\ 0 & \text{Otherwise.} \end{cases}$$

Then the total revenue gained from n EVs can be formalized as,

$$R(x_i) = \sum_{i=1}^{n} v_i x_i \qquad (2)$$

Given revenue model above, we consider an admission control problem to choose a set accepted EVs $X = [x_i]_{1\times n}$. This is captured by the following optimization problem:

$$\begin{aligned} &\text{Maximize} && R(x_i) \\ &\text{Subject to} && \sum_{i=1}^{n} \omega_i x_i \le C \qquad (3) \\ & && x_i \in \{0,1\},\ \forall i \end{aligned}$$

This problem is known as Knapsack problem which is well-known NP-hard problem [5-4]. In this study the MCMC method is applied to find the set EVs served that can give most revenue to parking station.

2.2. Markov Chain Monte Carlo based admission control mechanism

Algorithm 1: Markov Chain Monte Carlo based admission control mechanism (MCMC-ACM)

1. Initialization: Choose a feasible x^* and compute the optimal value R^* of the MCMC-ACM problem.

2. Obtain x' and the corresponding optimal value $R' = R(x')$ by continuously picking randomly EV i and toggle value of x_i until violate the constraint

$$\sum_{i\in\mathcal{E}'} \omega_i x_i \le C \qquad (5)$$

3. Compute the transition probability

$$p = 1 - \frac{\exp(\beta R')}{\exp(\beta R') + \exp(\beta R^*)} \qquad (6)$$

4. With probability p, the controller sets $x^* \leftarrow x'$ and $R^* \leftarrow R'$. With probability $1-p$, the controller keeps the current state.

5. Return to Step 2 until the stopping criteria is met.

MCMC is a stochastic optimization method that can achieve the global optimal solution by probabilistically transitioning among possible states in the solution space [6-5].

In this study, we design an admission control mechanism based on Markov Chain Monte Carlo named MCMC-ACM for short.

In the problem (3), it is supposed that there are M subset of EVs that can satisfy the constraints. To apply MCMC method, each subset is considered as a possible state of Markov Chain as shown in Fig. 2. The system moves from one state to another based on total revenue R with probability p calculated by (6).

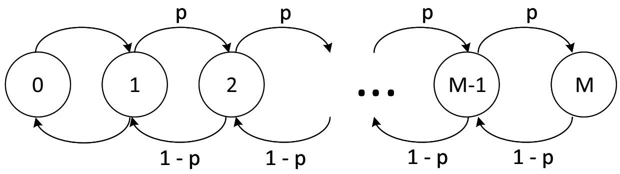

Figure 2: Markov Model corresponding to our model

The detail algorithm is illustrated in Algorithm 1. The parameter $\beta > 0$, referred to as the tunable smoothing parameter, is used to control exploration versus exploitation.

3. Simulation Results

In this section, we perform simulations to evaluate the performance of our proposed algorithm. The default simulation setting is revealed from [1,7]. There is one local area and 50 EVs. The local peak constraint is set from 125kWh to 500kWh corresponding network size from 50 to 200 [1]. The demand of each EVs is following a uniform distribution from 10kWh to 25kWh [3]. The electricity selling price is selected as 15.0¢/kWh [7].

We compare our proposed approaches with two other approaches: 1) The first approach is random greedy algorithm. The central aggregator will randomly choose a subset EVs that satisfying global peak constraint. 2) The second approach is optimal algorithm. A solution of the optimization problem (3) is found using general solver, the GUROBI optimizer [7]. Results corresponding to the random greedy and optimal algorithms are denoted as “Greedy”, and “Optimal”, respectively.

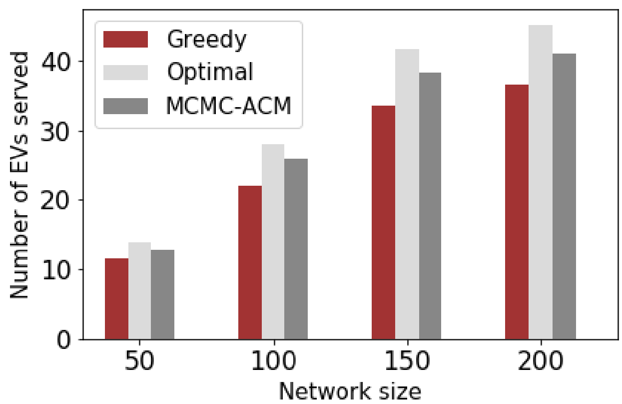

Figure 3: Average number of served EVS under different network sizes

The average number of served EVs under different network size is shown In Fig. 3. First, we find that our proposed outperforms the Greedy algorithm as the network size grows. Besides, MCMC-ACM has a close proximity of optimal algorithm. Our admission control can guarantee that a best seed set of EVs that maximize total benefit for utility provider has large number of EVs as much as possible. In other hand, the proposed can also bring benefit for the user side, EVs, when the number of served EVs is higher than that number in greedy algorithm.

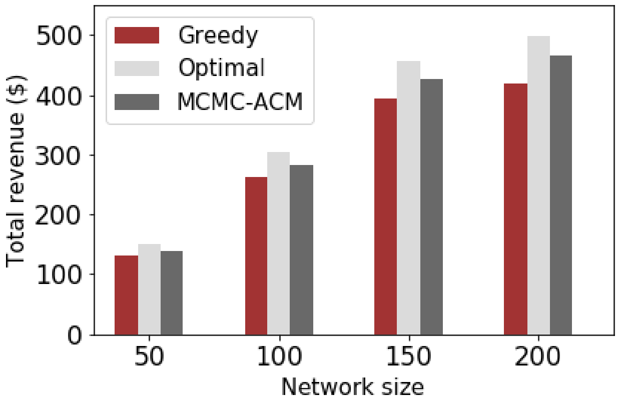

Figure 4: Average total revenue with different network sizes

Figure 4 compares the performance of MCMC-ACM, Greedy, and Optimal in term of average total of revenue. The result demonstrates that MCMC-ACM not only can increase the number of EVs but also get more total revenue compared with Greedy method. The value got from MCMC-ACM is not smaller than optimal method much under various scenarios with different network size.

4. Conclusion

In this study, an efficient admission control mechanism is designed based on Marko Chain Monte Carlo. The simulation results illustrate that proposed algorithm has a close proximity result to optimal algorithm in both total revenue and number of served EVs. In addition, proposed algorithm outperforms compared to greedy algorithm under various simulation scenarios.

Matching strategy and optimal scheduling policy are address as our future work.

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