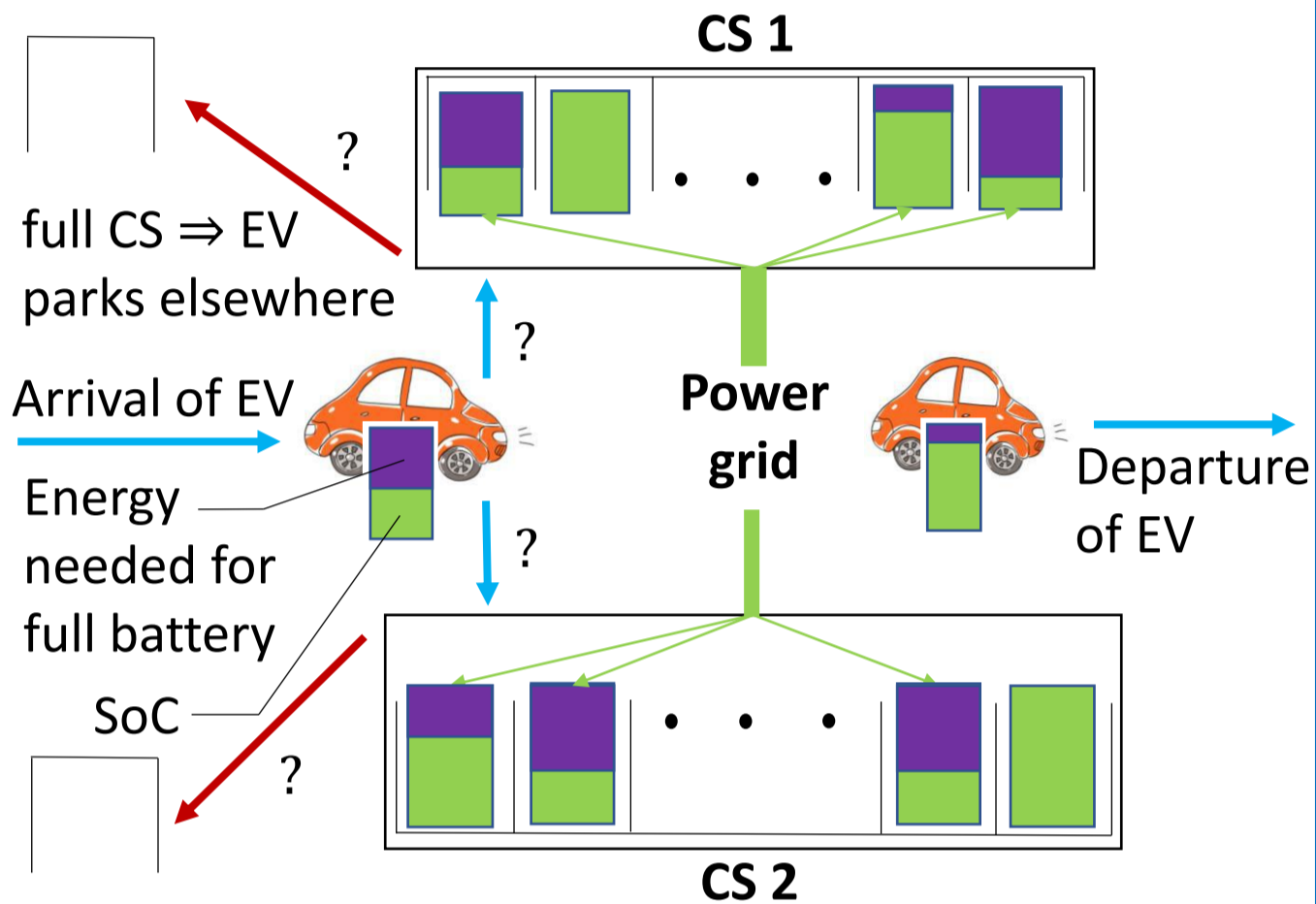


Context

- Two Charging Stations (CS) at the same site (e.g. a shopping center, a workplace);
- Electric Vehicles (EV) users choose a CS where they will park and recharge.



Choice of the CS: a queueing game

- EV users choose CS with highest QoS;
- QoS at each CS depends on the proportion of EVs choosing this CS;
- EV users interact through a queueing game⁴, where they are perfectly rational.

Definition and properties of equilibrium

- Equilibrium: allocation of EVs to the CS such that no EV has an incentive to unilaterally change its choice;
- Prop. 1: exists and is unique;
- Prop. 2: in general not socially optimal in terms of QoS.

Power sizing decision: improving the QoS

A Charging Station Operator (CSO), responsible for the two CS, can be interested to know the optimal power sizing to maximize EV users satisfaction. See Figure.

	CS 1	CS 2
Number $N_{p,i}$ of parking spaces	10	30
Maximum power $p_{max,i}$ per CP	75 kW	11 kW
Maximum total power P_{total}	250 kW	

Table: parameter values characterizing the two CS

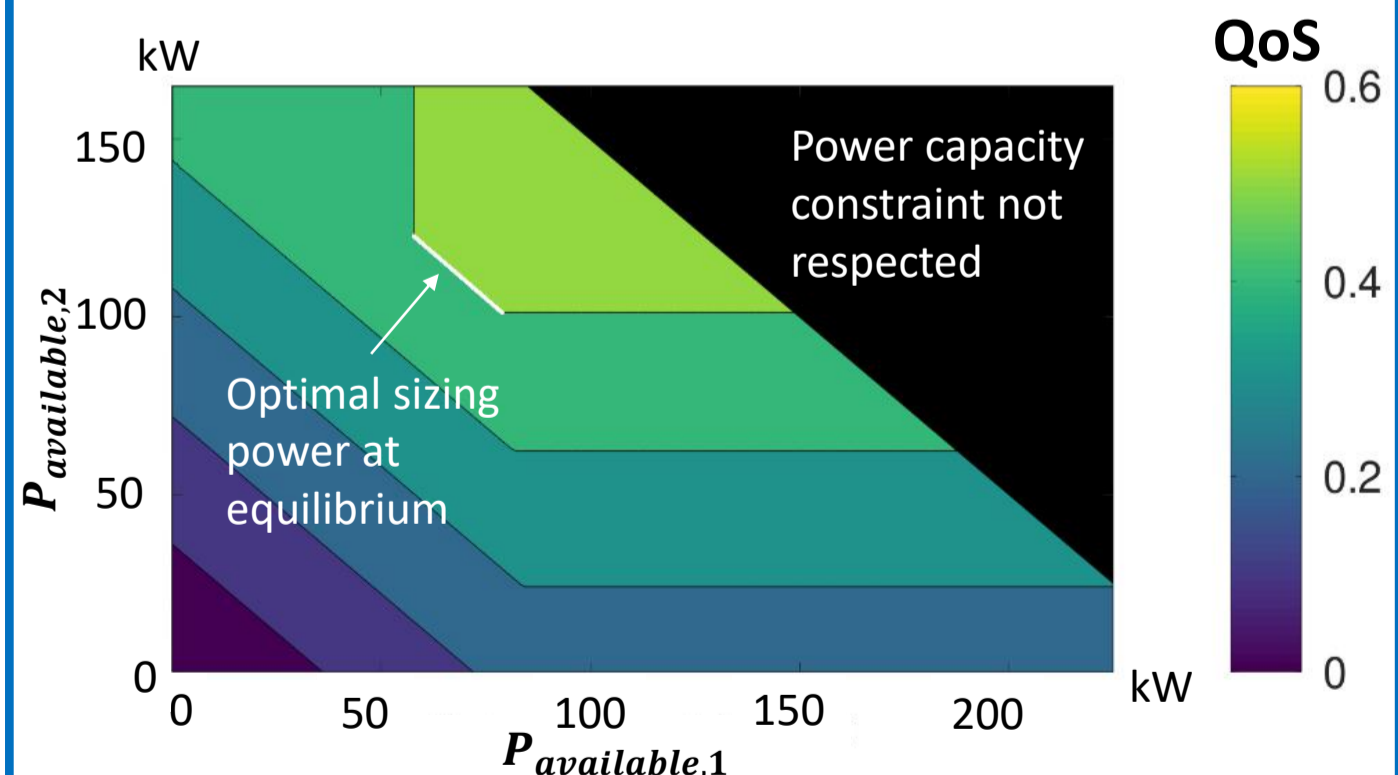


Figure: QoS as a function of the sizing power allocation to the two CS.

EV characteristics and CS limitations

- Random inter-arrival time, State of Charge (SoC), and parking duration¹;
- A fixed nb of parking spaces $N_{p,i}$ at CS i , all equipped with one Charging Point (CP) with max power $p_{max,i}$;
- A total available power $P_{available,i}$ at CS i ;
- A total available power P_{total} at the two CS:

$$P_{available,1} + P_{available,2} \leq P_{total}$$

Scheduling method: a smoothing² policy

- N_{CEV}^i = nb of EVs at CS i actually charging;
- At each CS i , power shared through:

$$p_i(N_{CEV,i}) = \frac{\min(P_{available,i}, p_{max,i} \times N_{CEV,i})}{N_{CEV,i}}$$

- Quality of Service³ (QoS):

$$\mathbb{P}(\text{CS not full}) \times \mathbb{P}(\text{charging_duration} \leq \text{parking_duration})$$

¹ Supposed exponentially distributed and independent.

² Also called *processor sharing*, already used by some CSO.

³ Proba to leave with a fully charged battery; an approximation is computed here.

⁴ There exists a rich literature on queueing game. See for instance "R. Hassin, M. Haviv *To Queue or Not to Queue*, 2003".