V2G at the University of Delaware

Stijn Vandael

EVGRID

MILBANK

Auto Port INC.

pjm

BMW

AC PROPULSION

nrg SM

UNIVERSITY OF DELAWARE

UD research group on Grid-Integrated Vehicles and Vehicle-to-Grid Power

UD research group on Grid-Integrated Vehicles and Vehicle-to-Grid Power

One of the project goals:

Design of a software system for large-scale control of EV (dis)charging to provide regulation services.

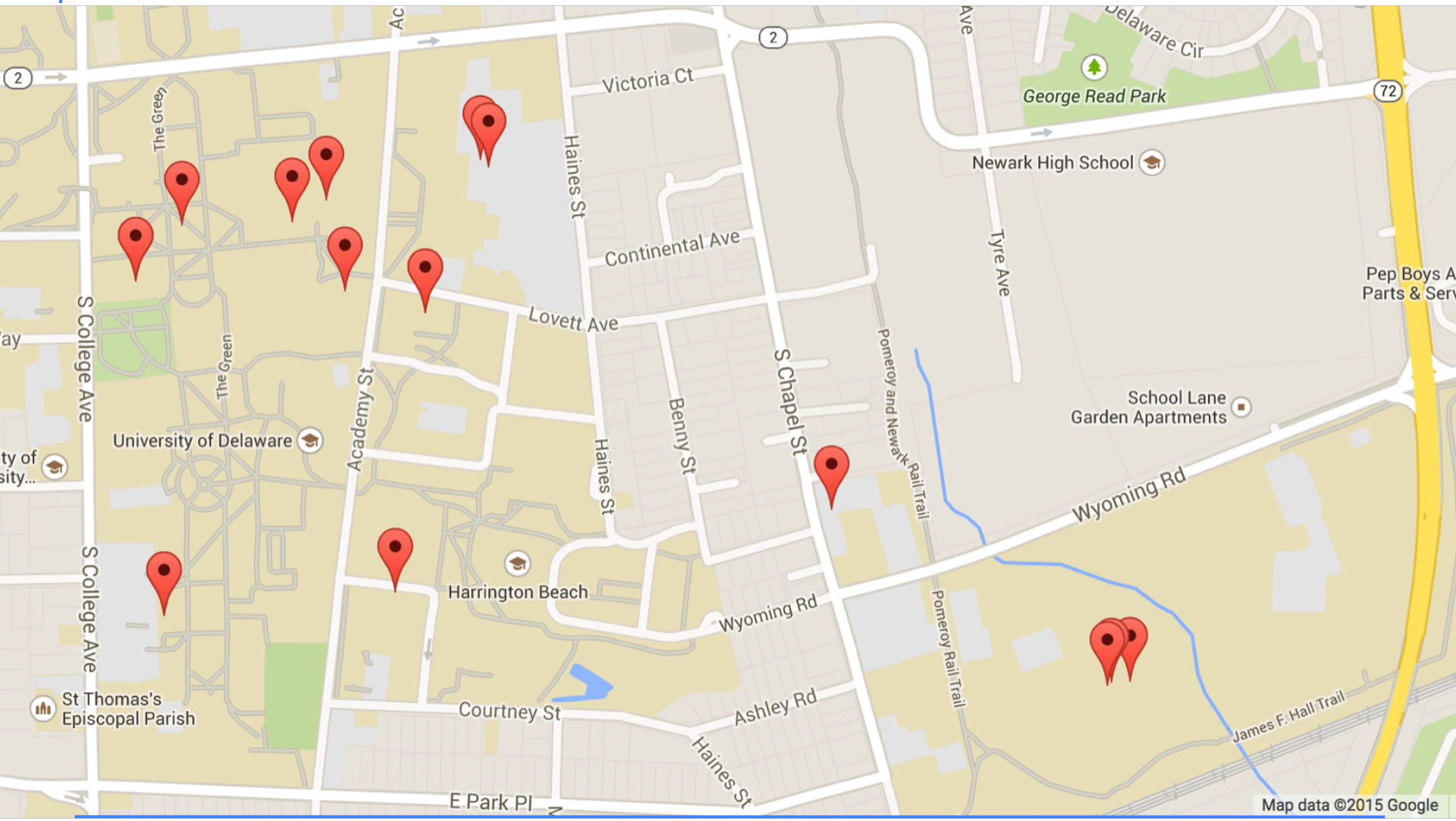
Overview

1. Regulation services at UD
2. Problem: large-scale scheduling
3. Solution: aggregate and dispatch
4. Evaluation
5. Validation

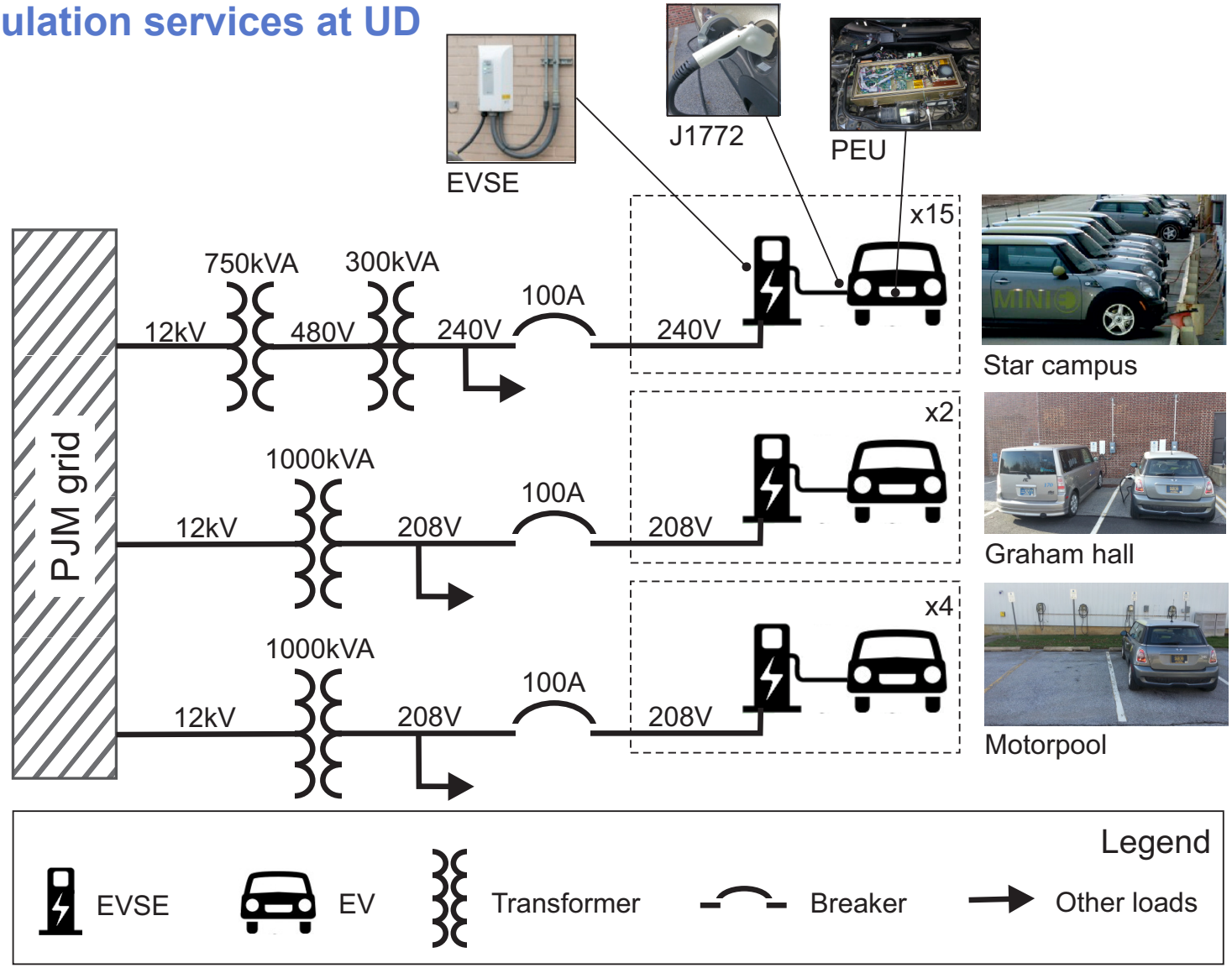
1. **Regulation services at UD**
2. **Problem: large-scale scheduling**
3. **Solution: aggregate and dispatch**
4. **Evaluation**
5. **Validation**

1. Regulation services at UD

1. Regulation services at UD



1. Regulation services at UD

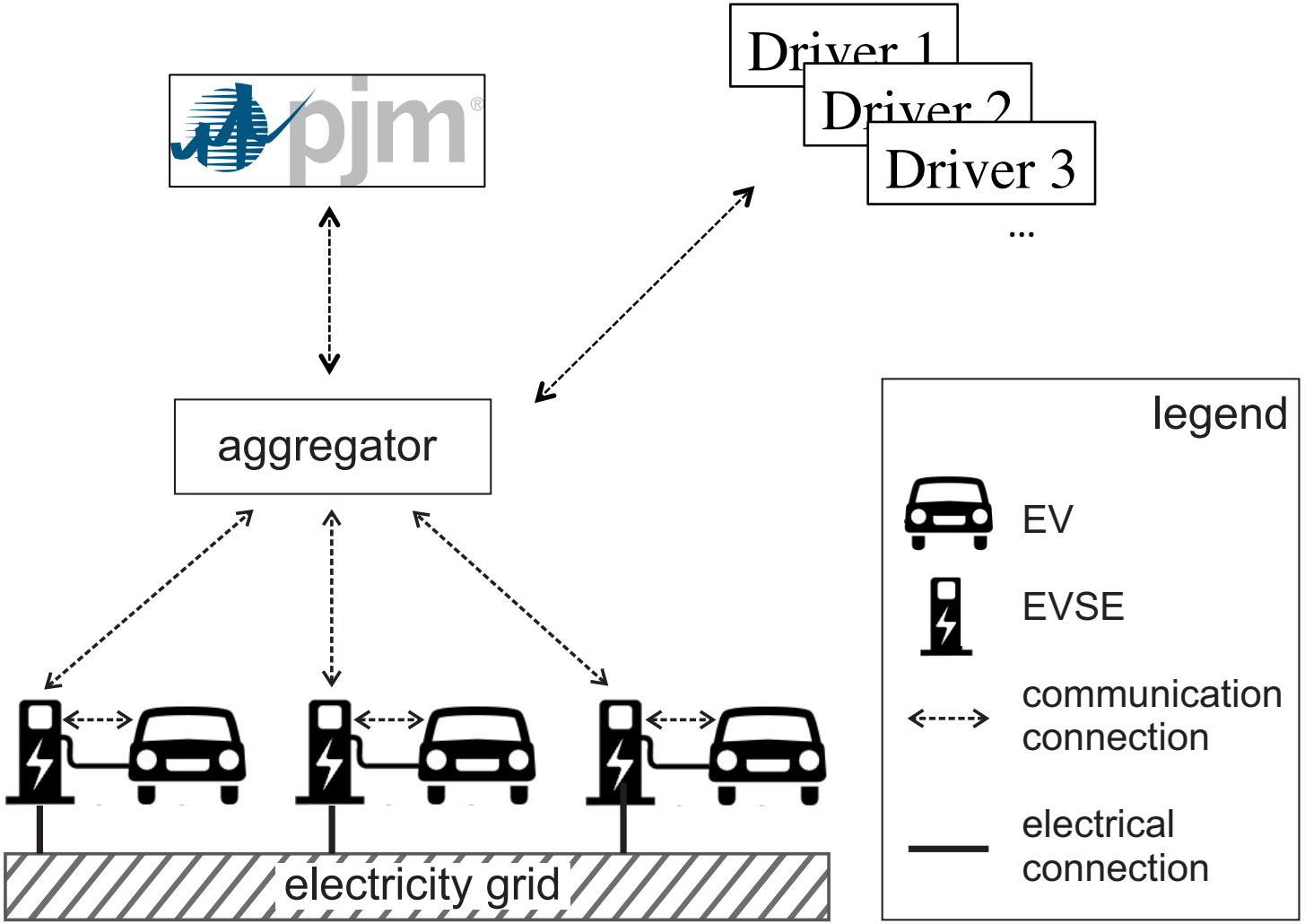


UNIVERSITY OF DELAWARE

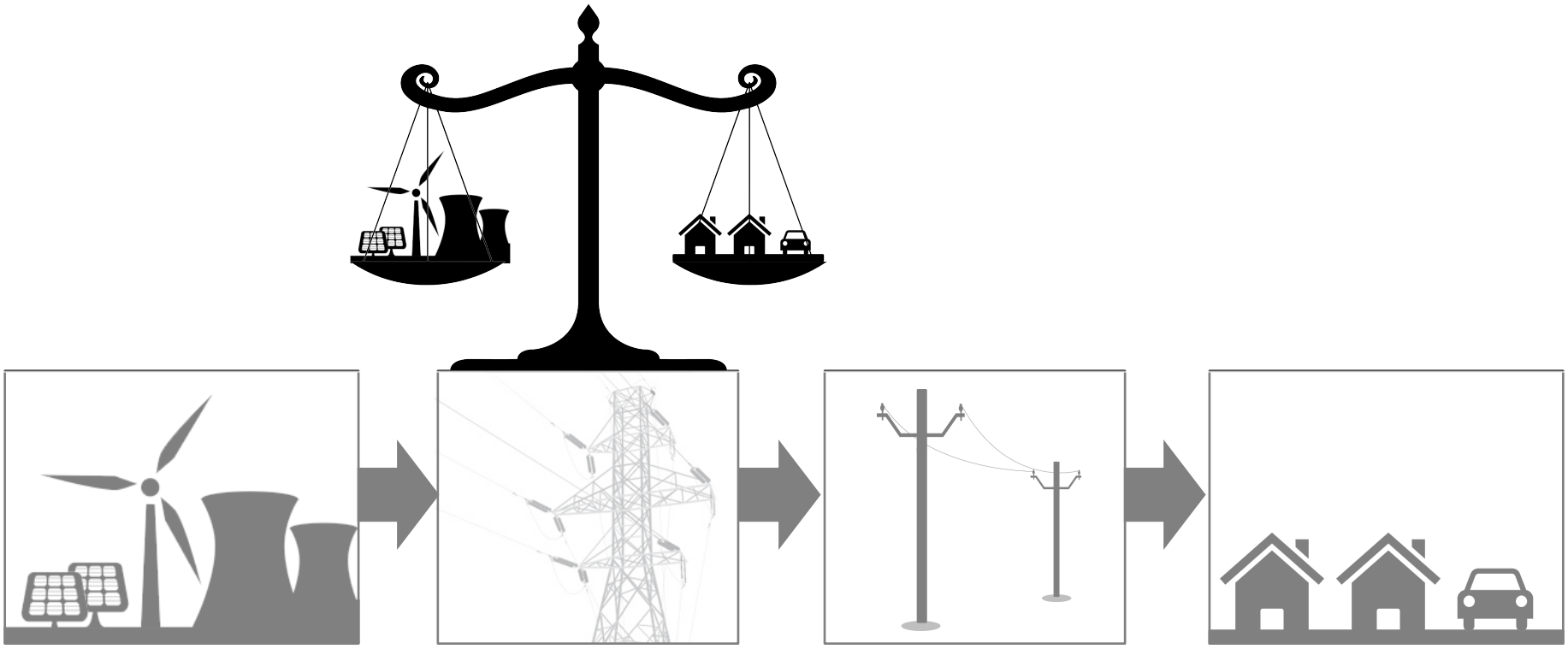
1. Regulation services at UD

UNIVERSITY OF DELAWARE

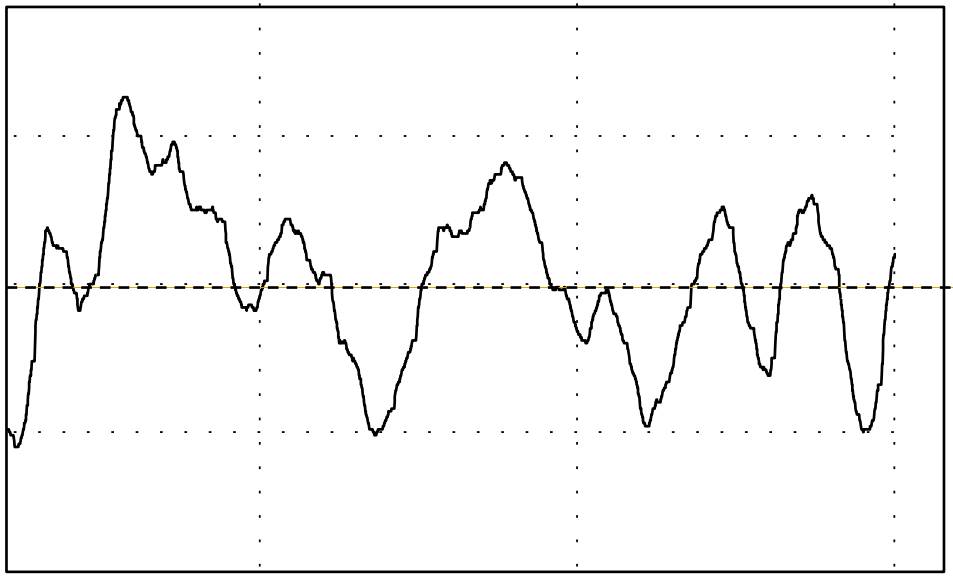
1. Regulation services at UD

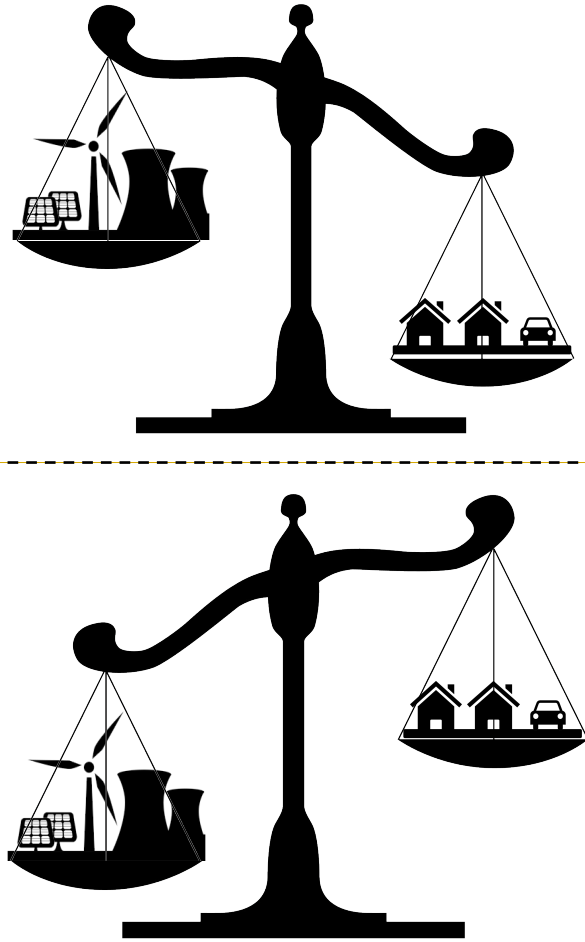


1. Regulation services at UD

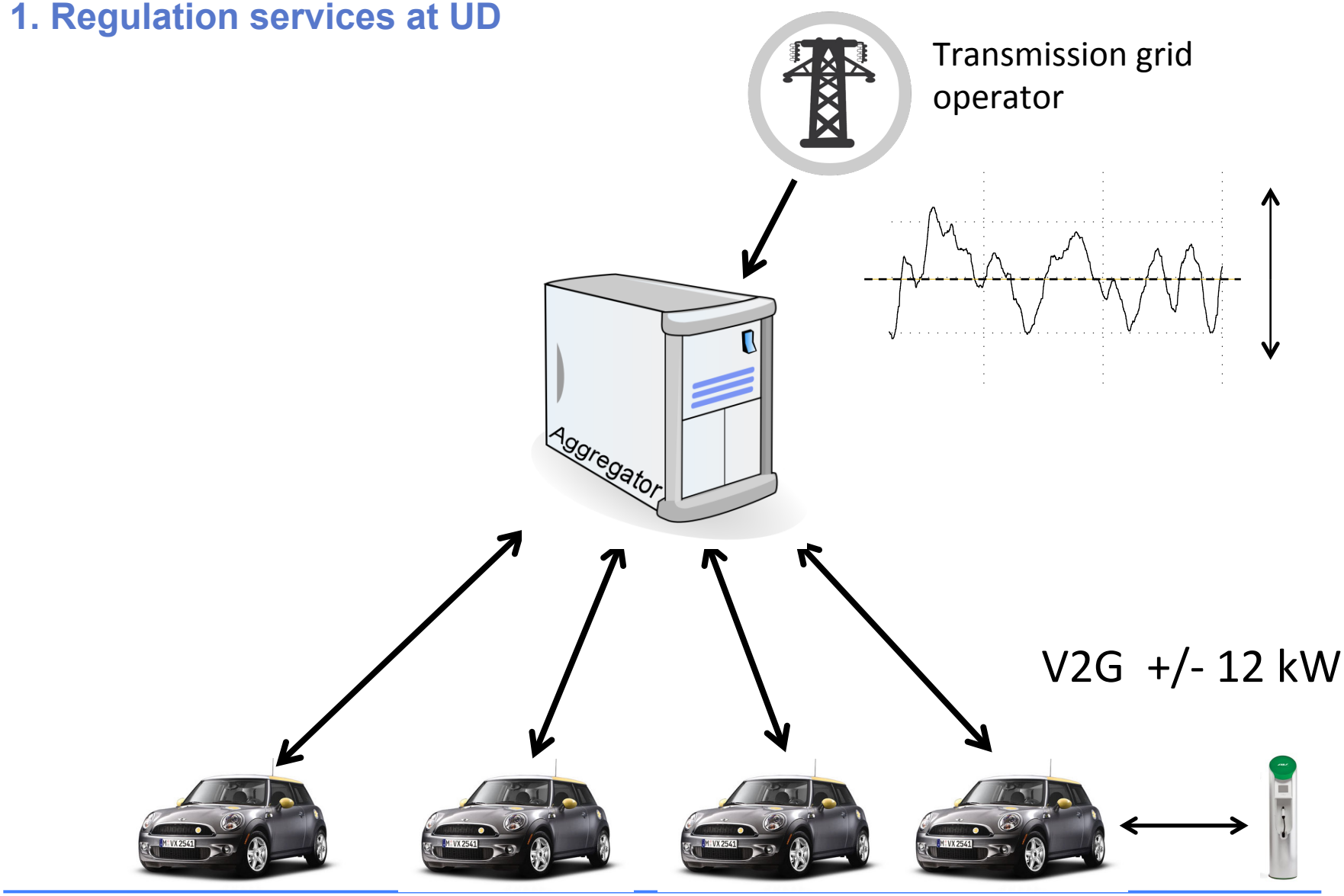


1. Regulation services at UD

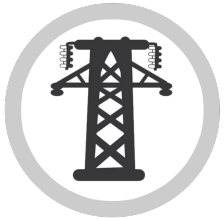




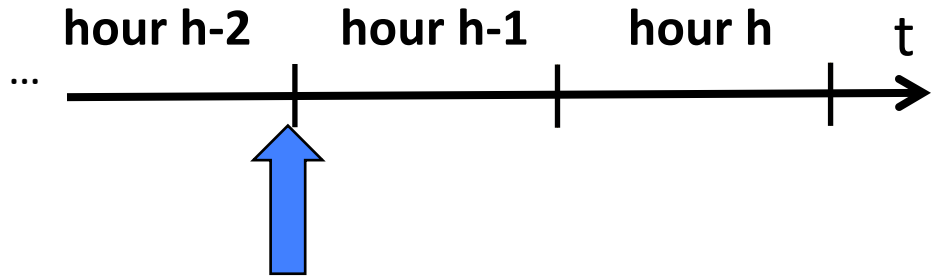
1. Regulation services at UD



1. Regulation services at UD



Aggregator

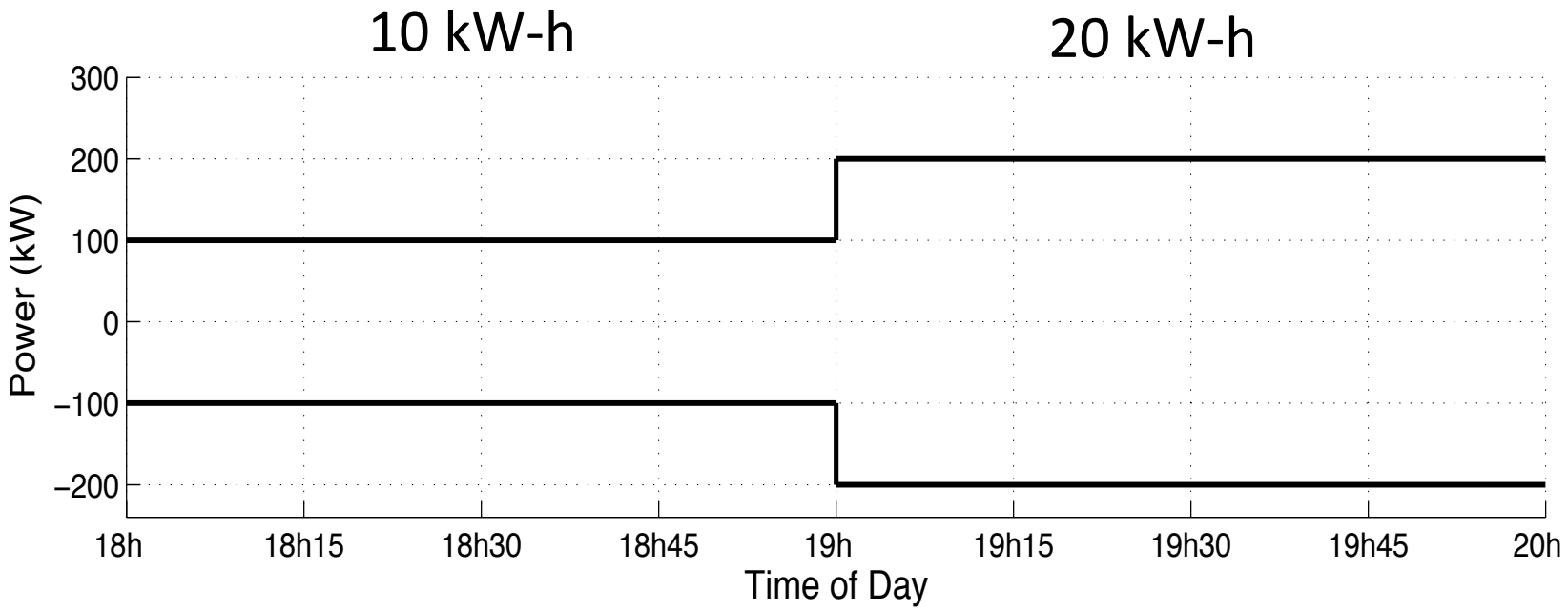


Before hour h-1
-> sell regulation capacity for hour h

E.g 20 kW-h

UNIVERSITY OF DELAWARE

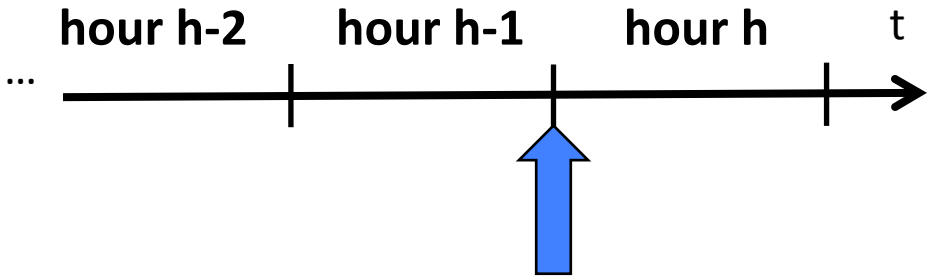
1. Regulation services at UD



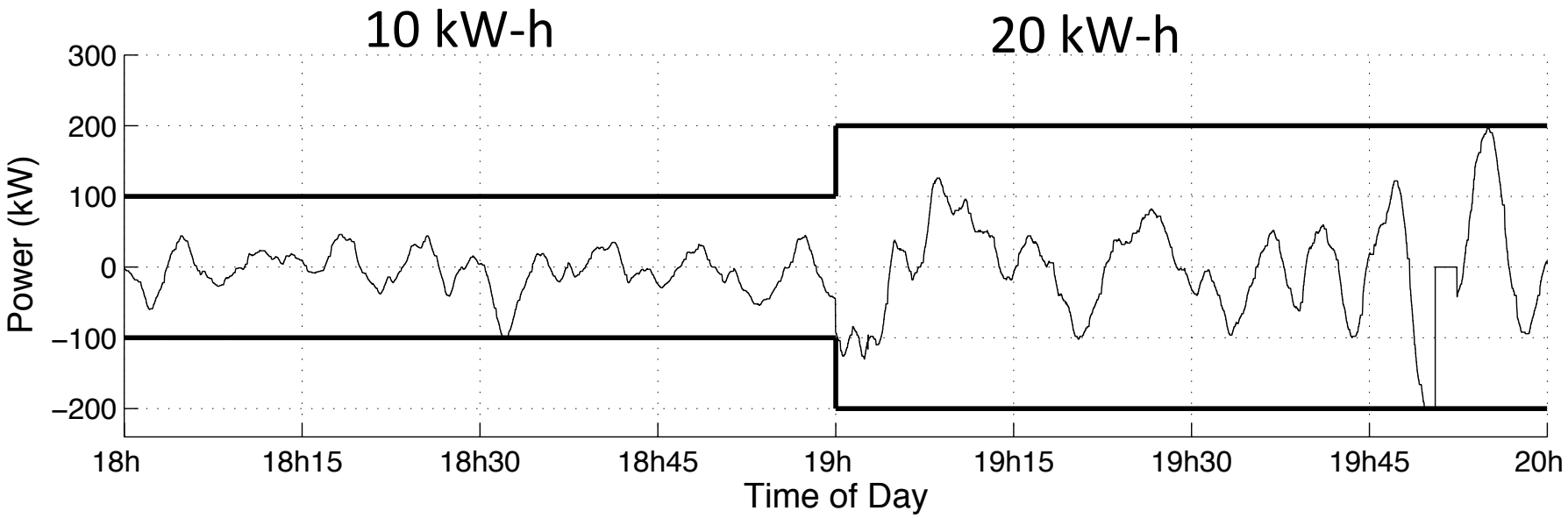
1. Regulation services at UD

Regulation market

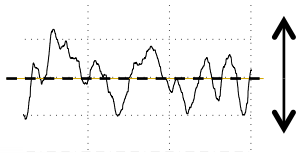
Aggregator



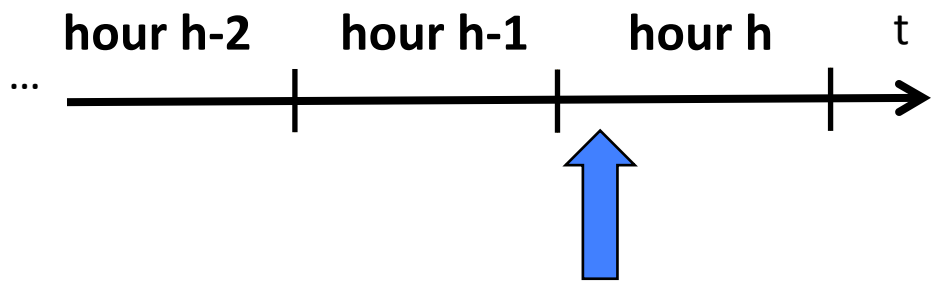
1. Regulation services at UD

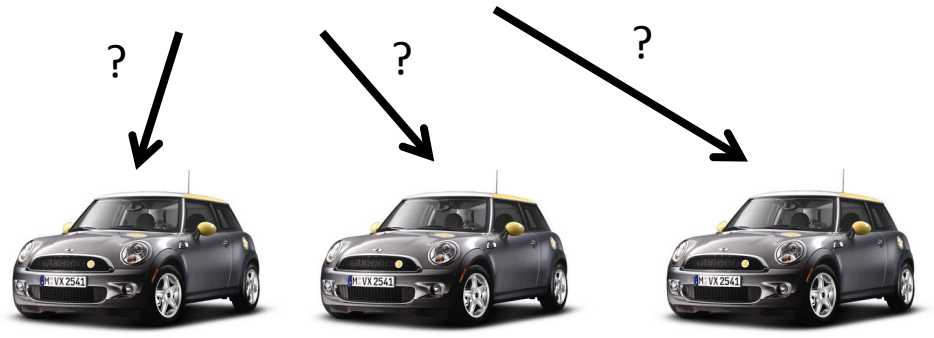


1. Regulation services at UD



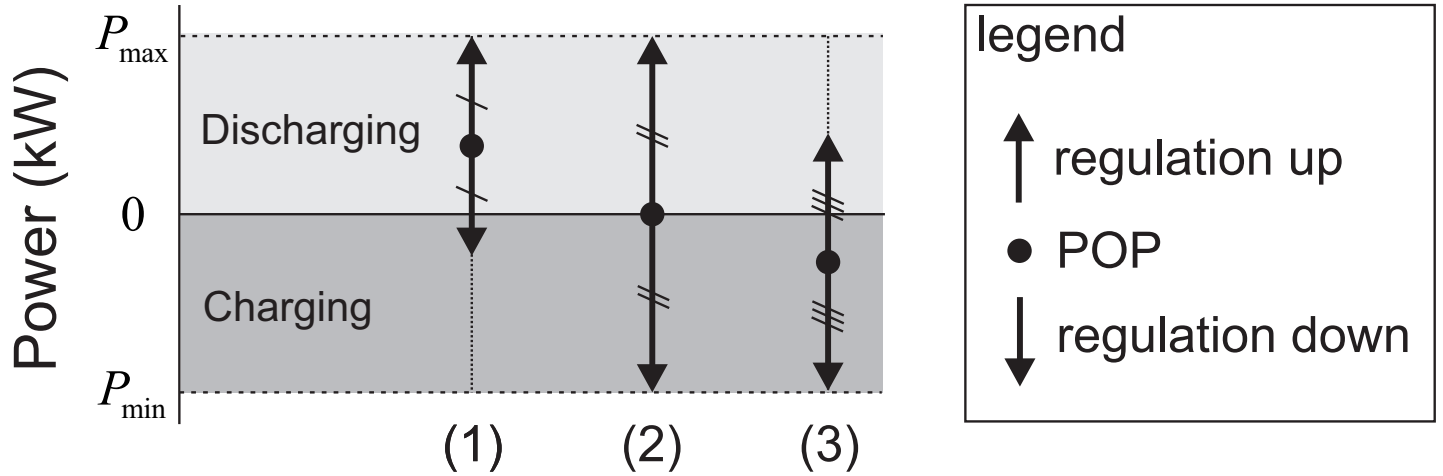
Aggregator



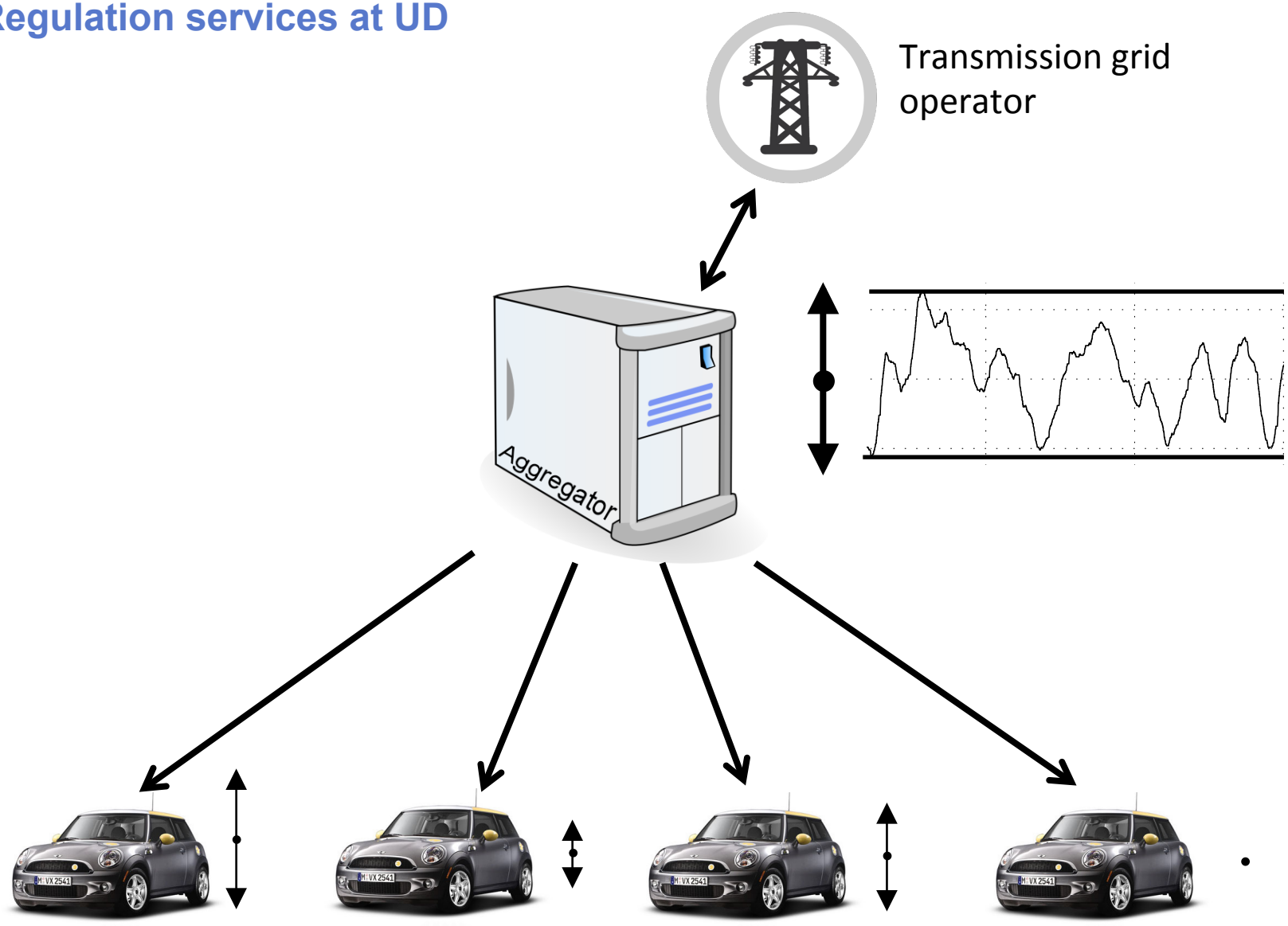


UNIVERSITY OF DELAWARE

1. Regulation services at UD



1. Regulation services at UD

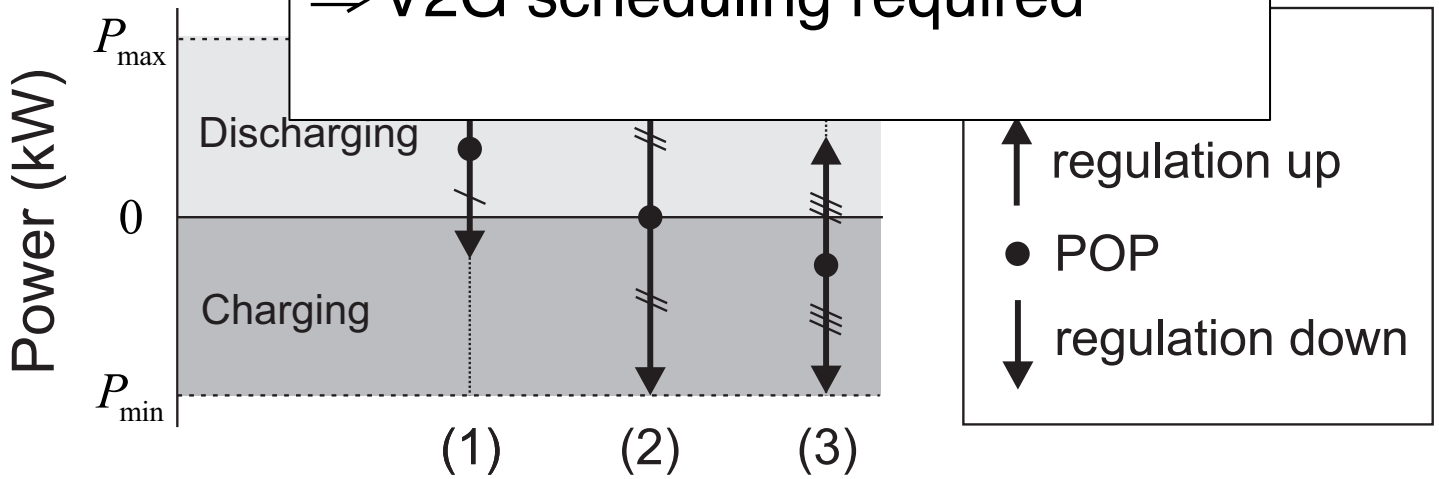


1. Regulation services at UD

Primary objective:

Charging EV before de

⇒ V2G scheduling required



Charging strategy objective:

Coordinate power transfer (charging and discharging) of EVs for providing regulation power, **while taking into account driver constraints.**

Overview

1. GIV at the University of Delaware
2. Problem: large-scale scheduling
3. Solution: bin-based approach
4. Evaluation
5. Validation

Overview

1. GIV at the University of Delaware

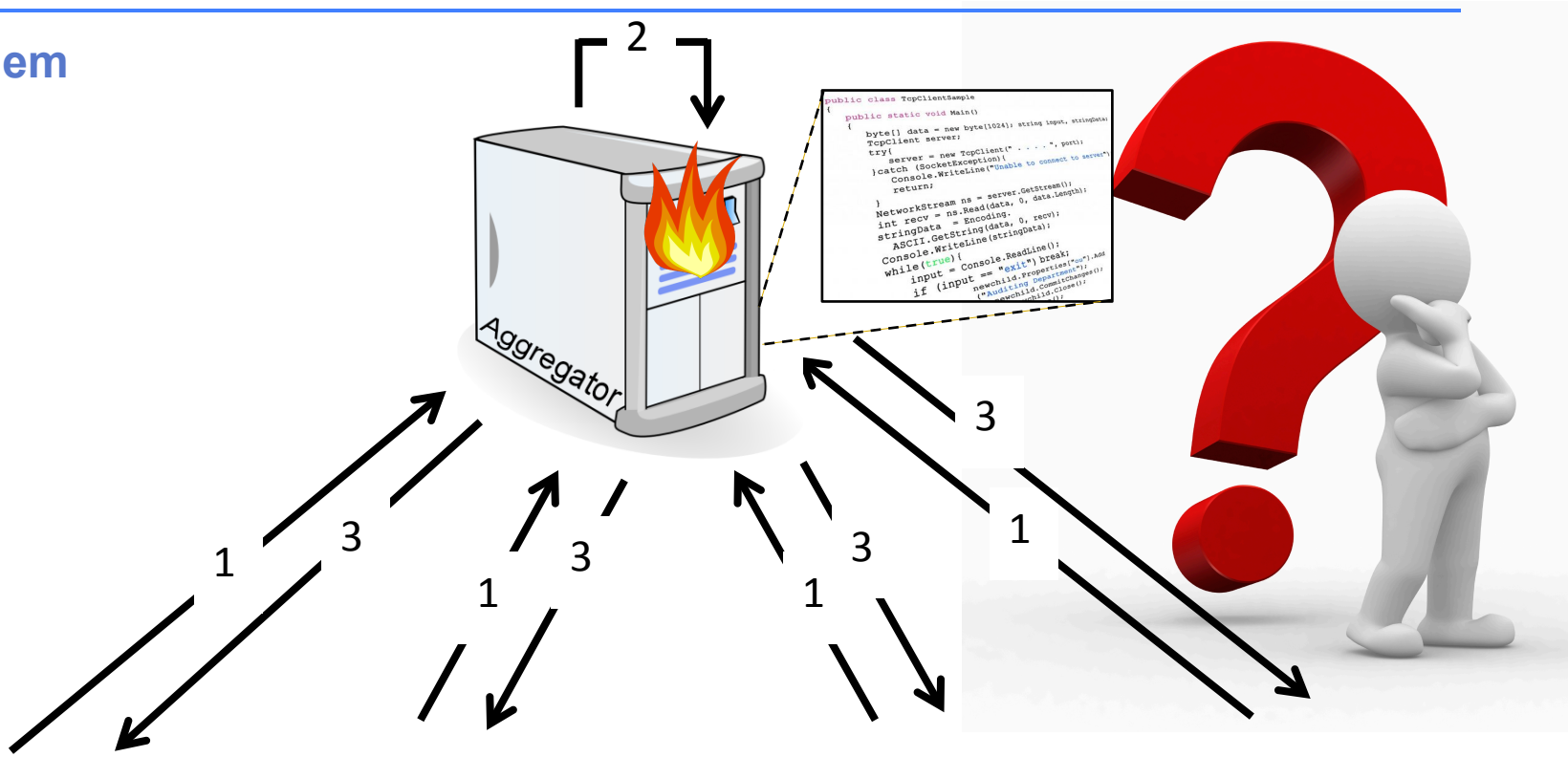
2. **Problem: large-scale scheduling**

3. Solution: bin-based approach

4. Evaluation

5. Validation

2. Problem



UNIVERSITY OF DELAWARE

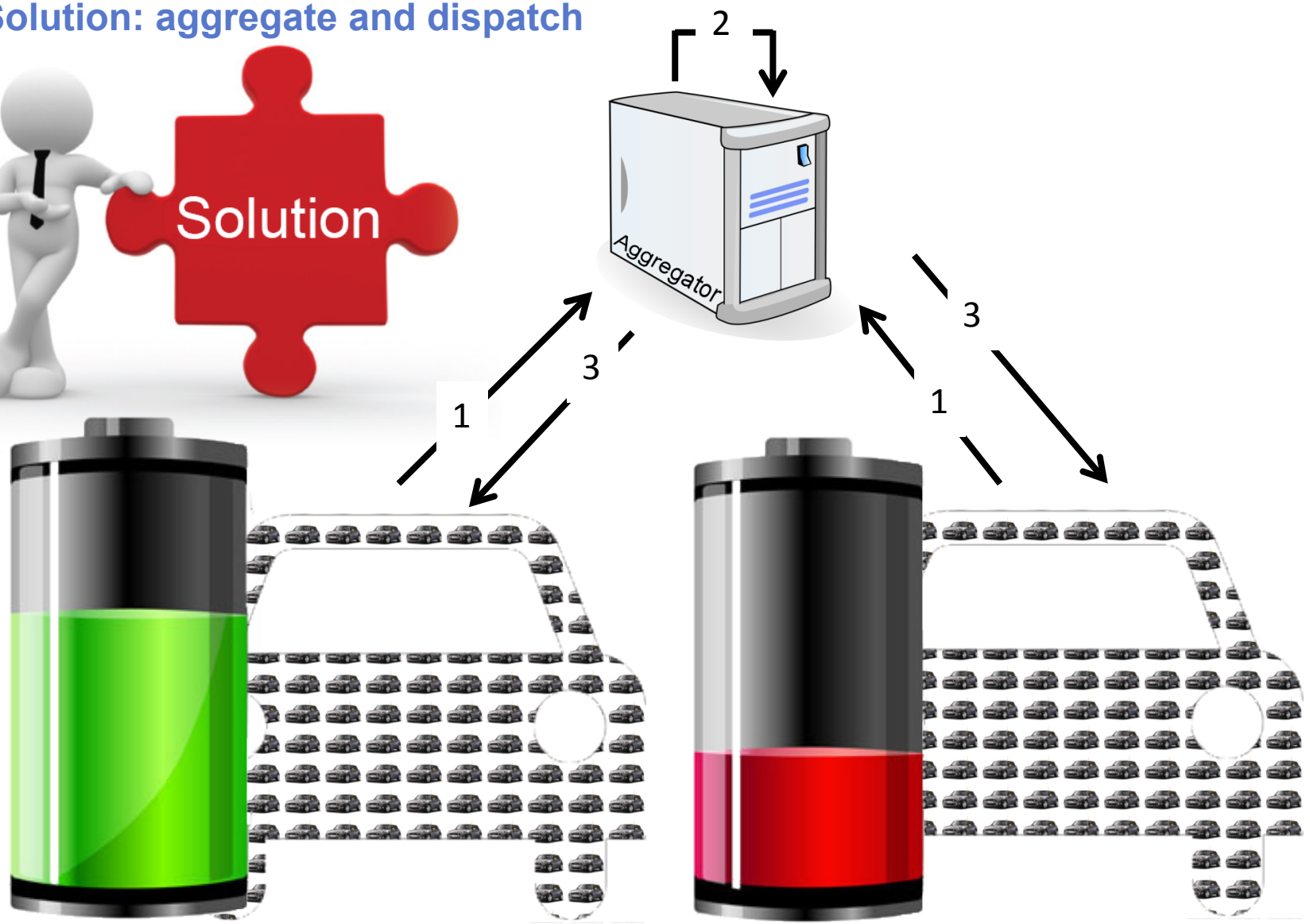
Overview

1. GIV at the University of Delaware
2. Problem: large-scale scheduling
3. Solution: aggregate and dispatch
4. Evaluation
5. Validation

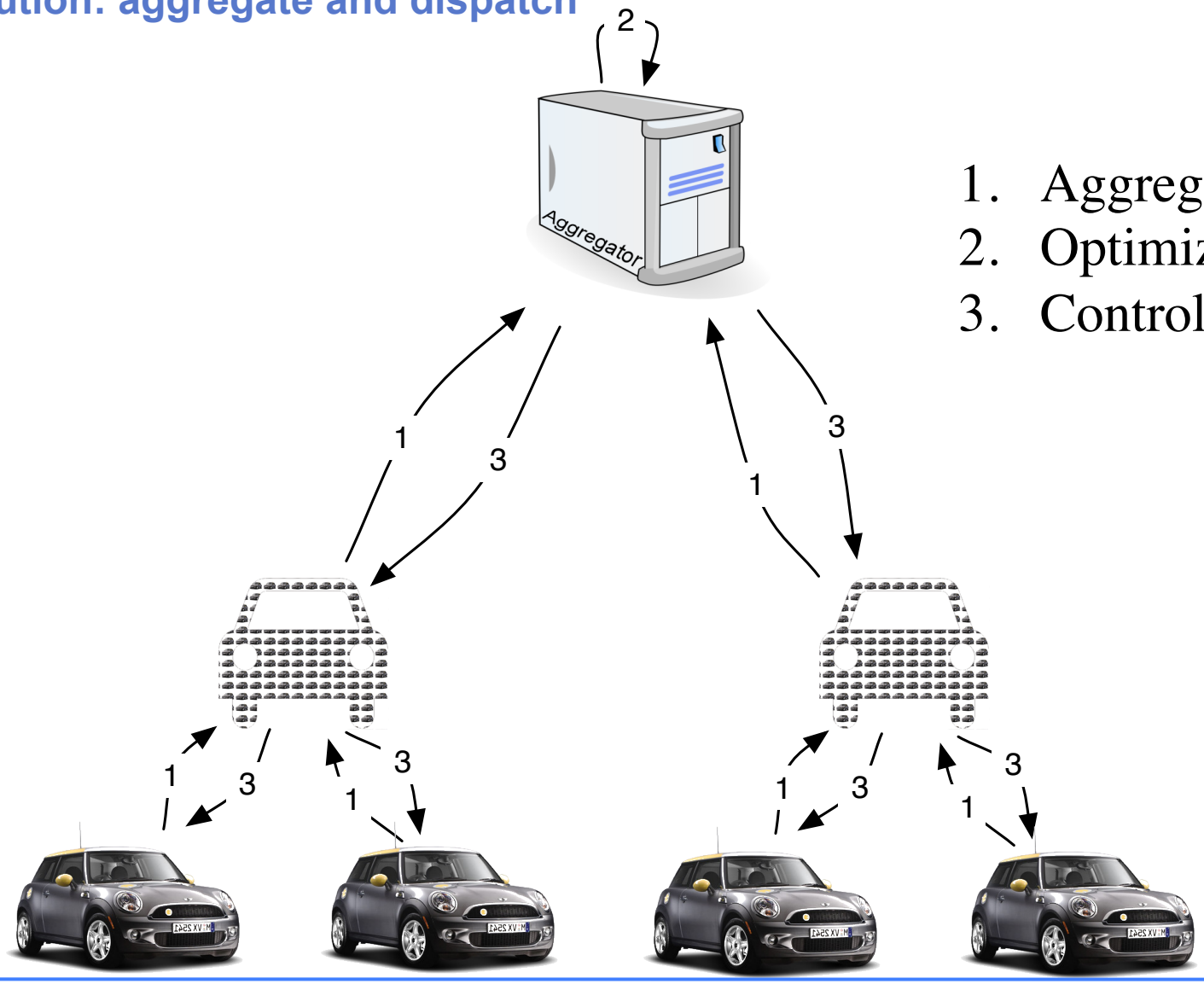
Overview

1. GIV at the University of Delaware
2. Problem: large-scale scheduling
3. **Solution: aggregate and dispatch**
4. Evaluation
5. Validation

Solution: aggregate and dispatch



Solution: aggregate and dispatch

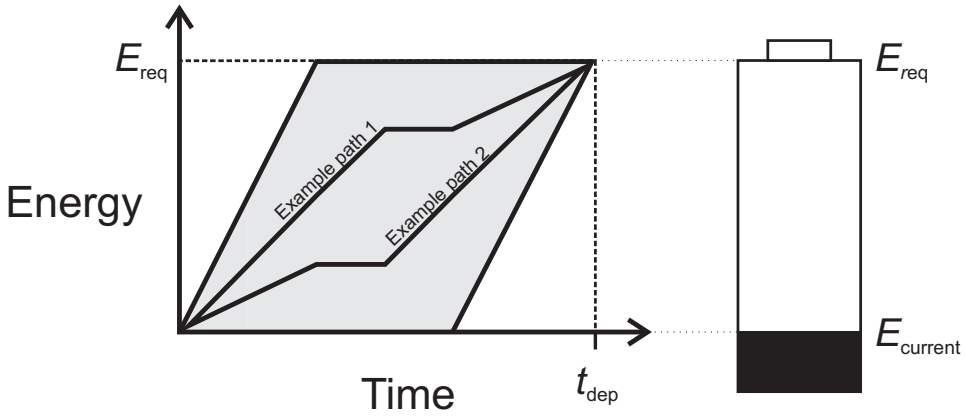


1. Aggregation
2. Optimization
3. Control

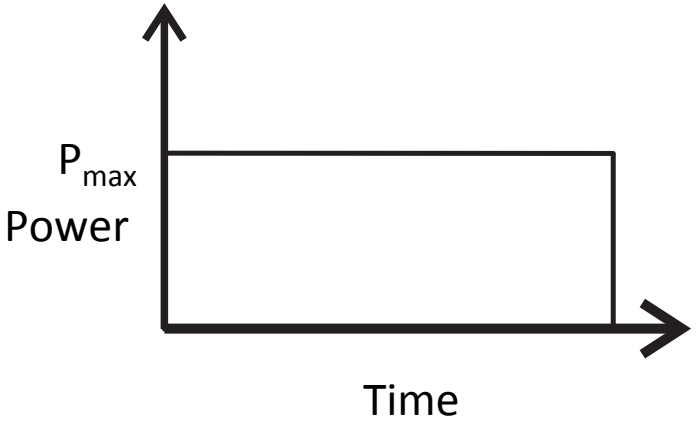
UNIVERSITY OF DELAWARE

Step 1

Energy flexibility

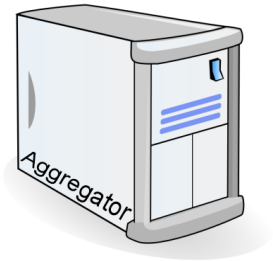


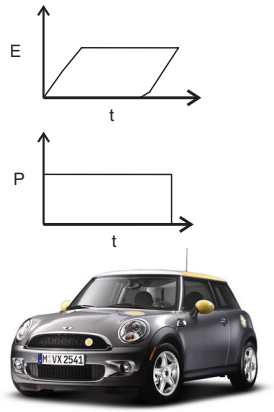
Power flexibility

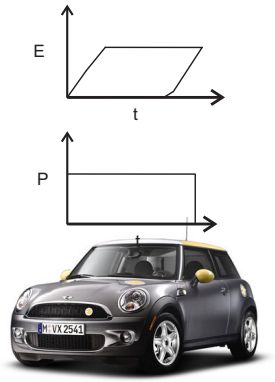


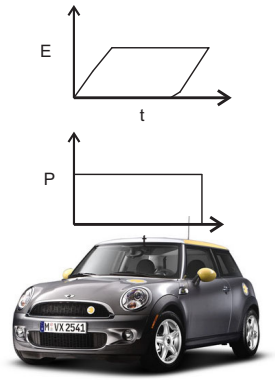
Solution

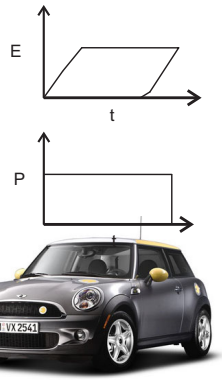
Step 1







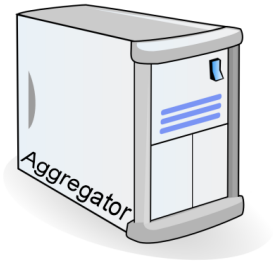


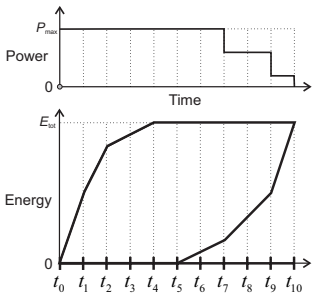


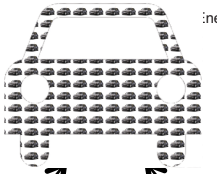
UNIVERSITY OF DELAWARE

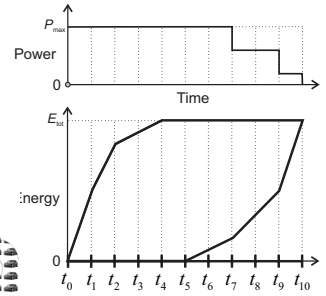
Solution

Step 1





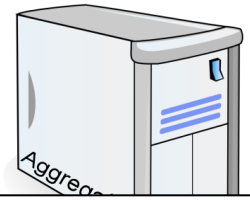




UNIVERSITY OF DELAWARE

Solution

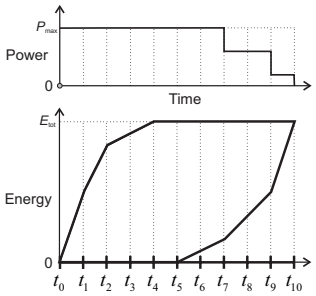
Step 1

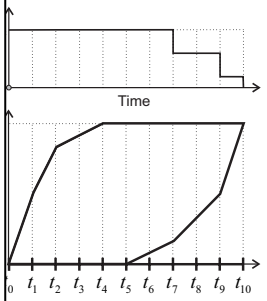


How classify electric vehicles?

Based on typical EV characteristics:

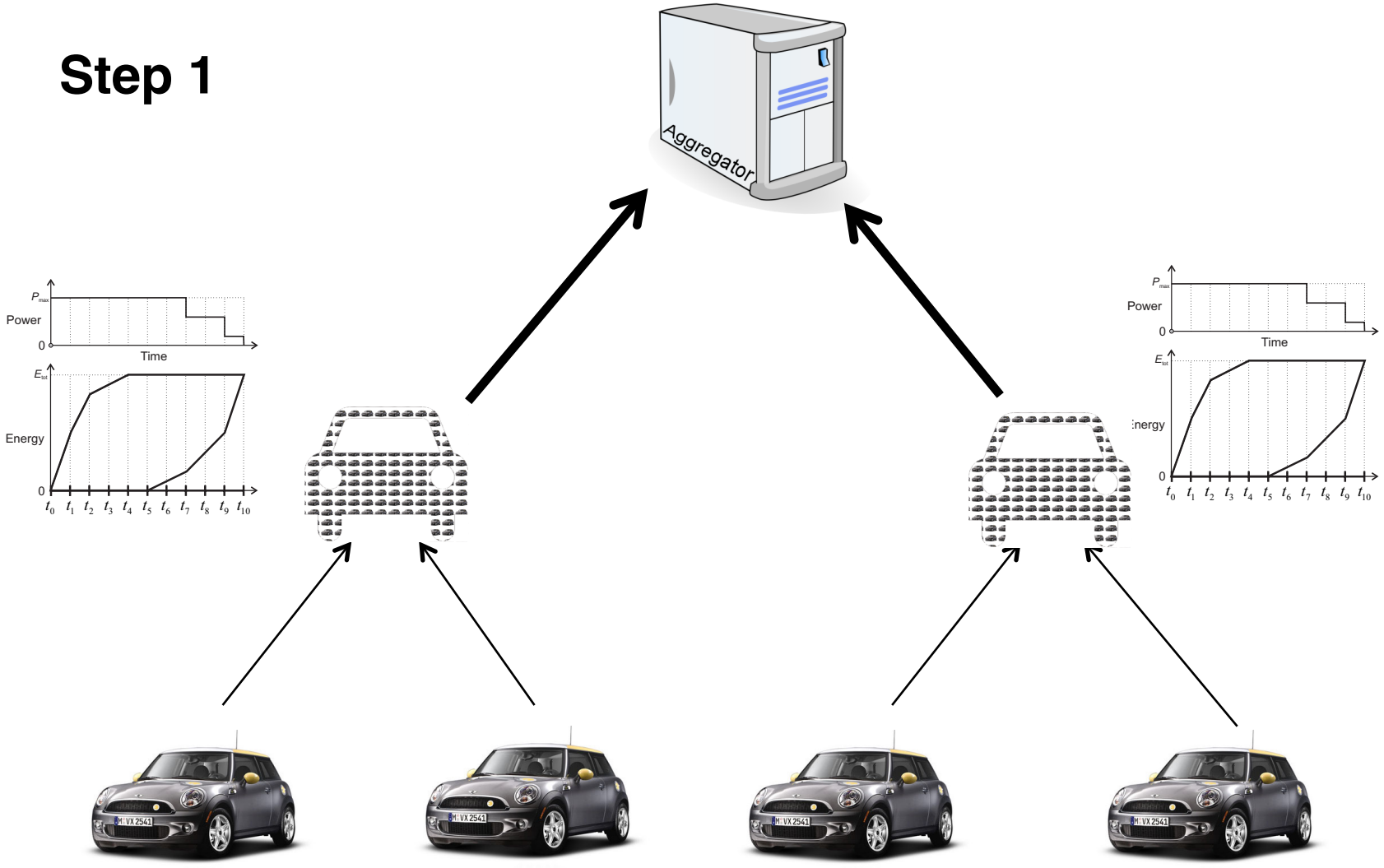
- departure time
- maximum power
- energy to-be-charged





Solution

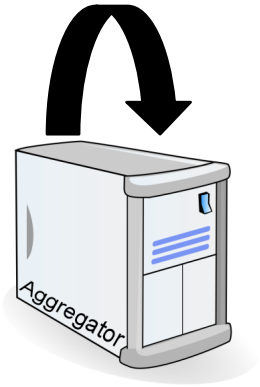
Step 1

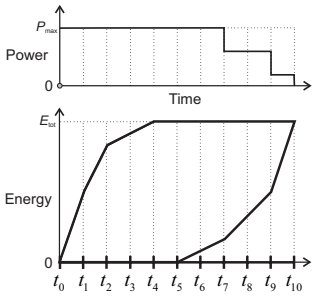


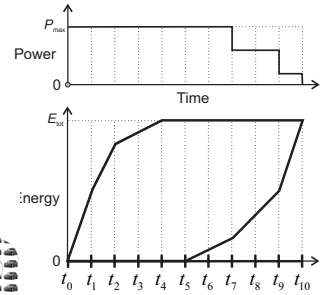
UNIVERSITY OF DELAWARE

Solution

Step 2



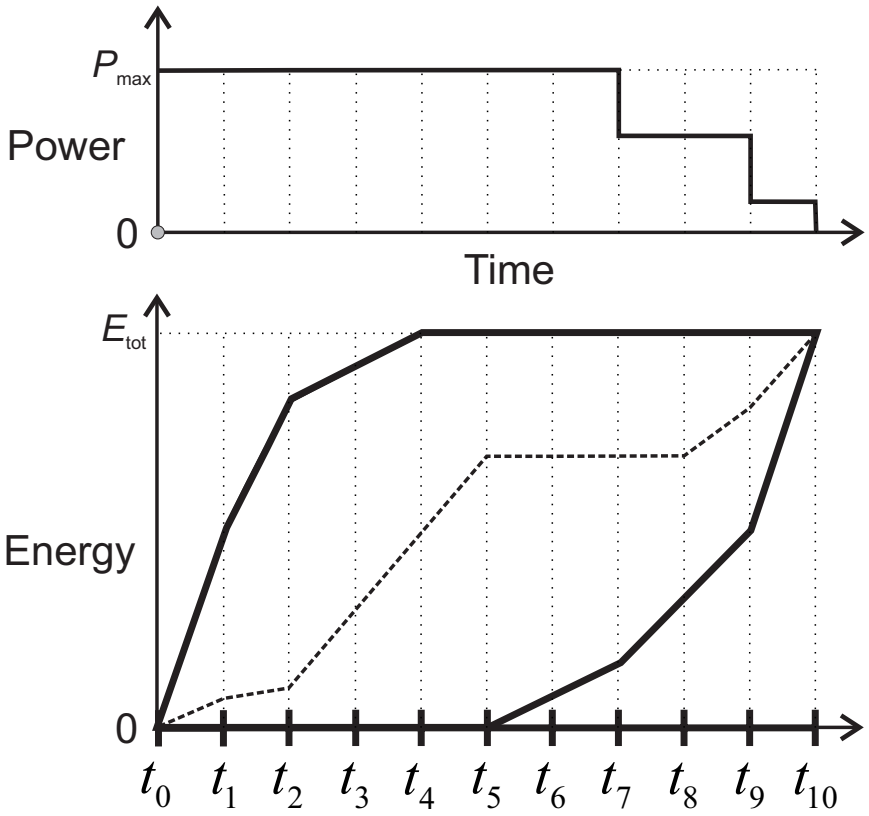


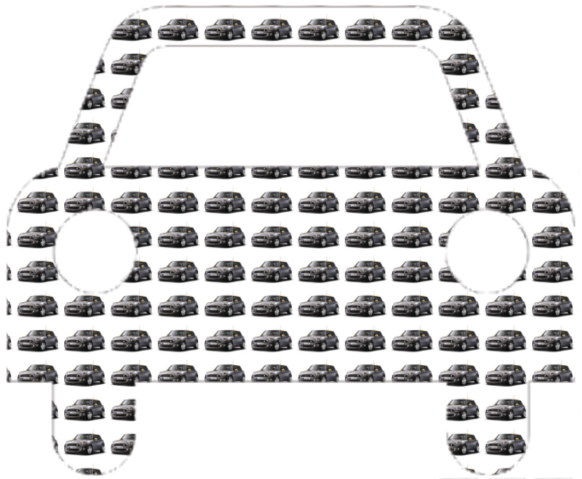


UNIVERSITY OF DELAWARE

Solution

Step 2



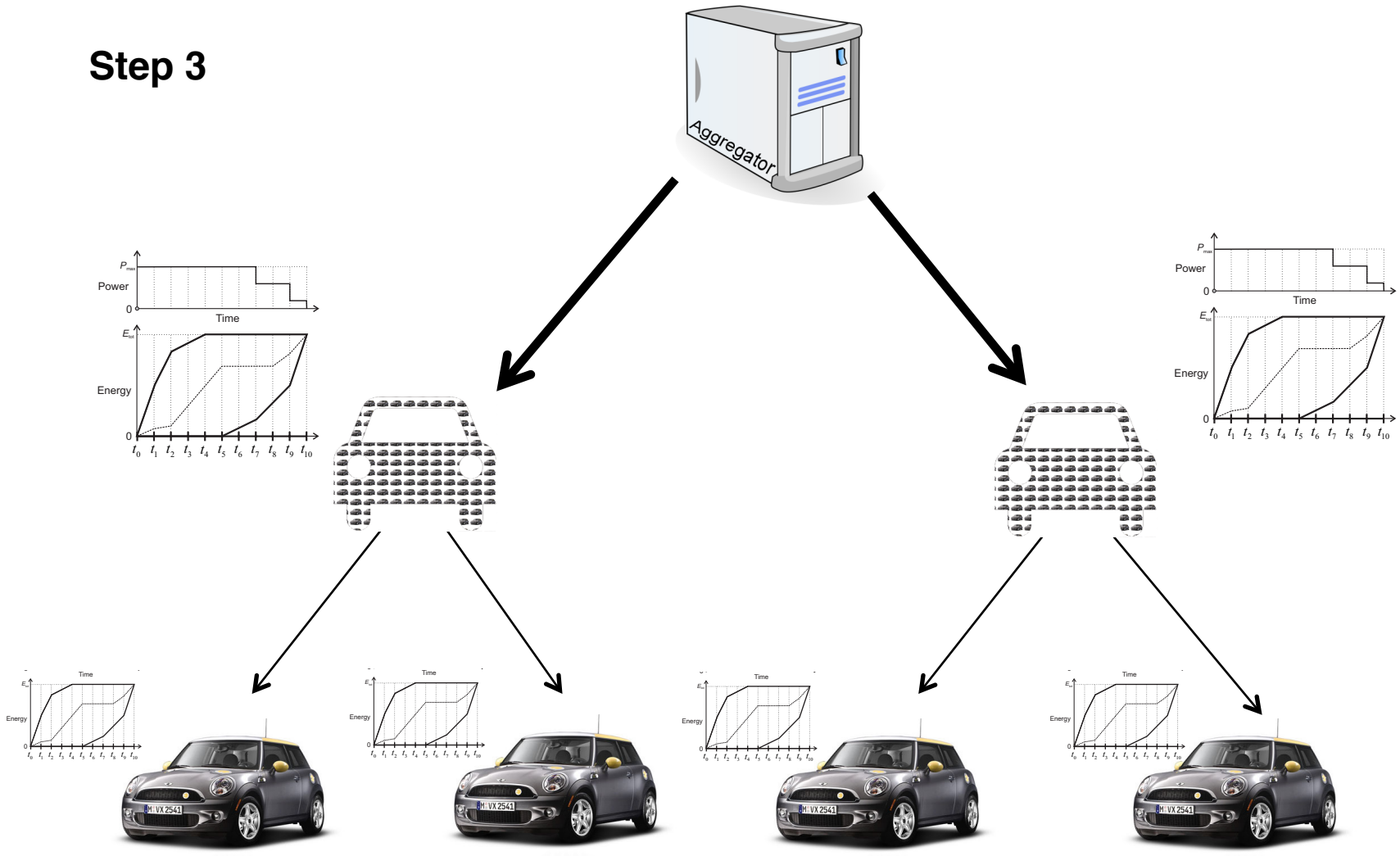


Solution through
lexicographic multi-objective optimization
(5 objectives)

UNIVERSITY OF DELAWARE

Solution

Step 3



UNIVERSITY OF DELAWARE

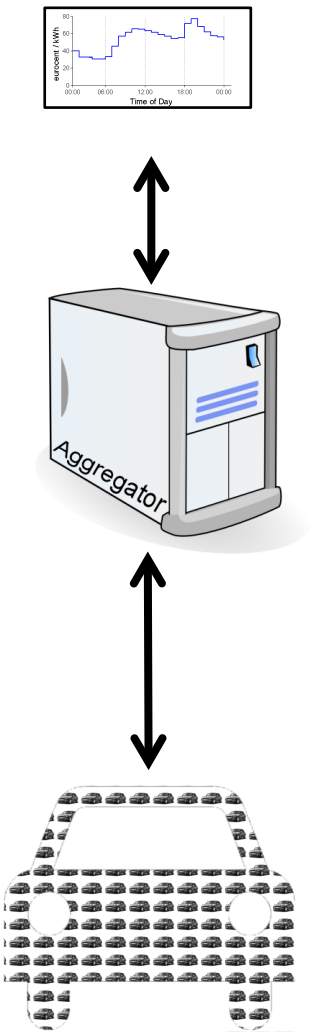
Overview

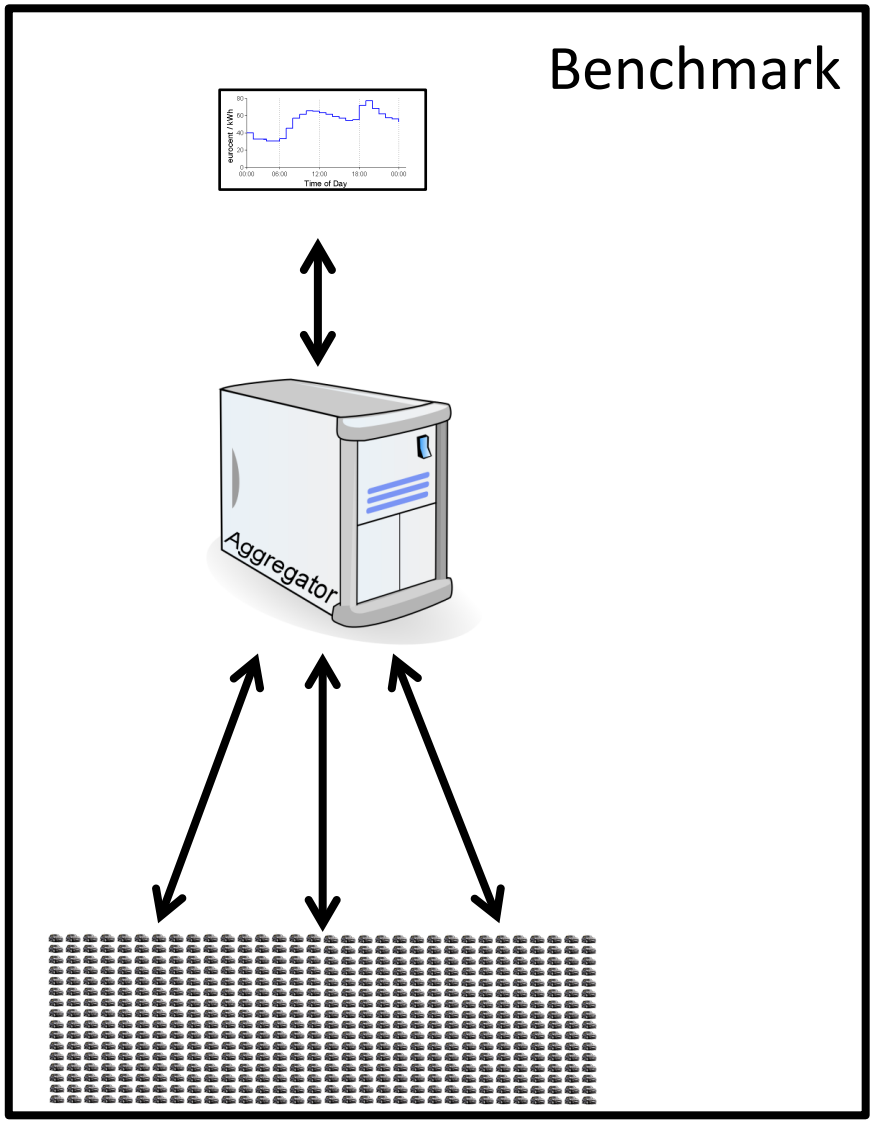
1. GIV at the University of Delaware
2. Challenge: large-scale scheduling
3. Solution: aggregate and dispatch
4. Evaluation
5. Validation

Overview

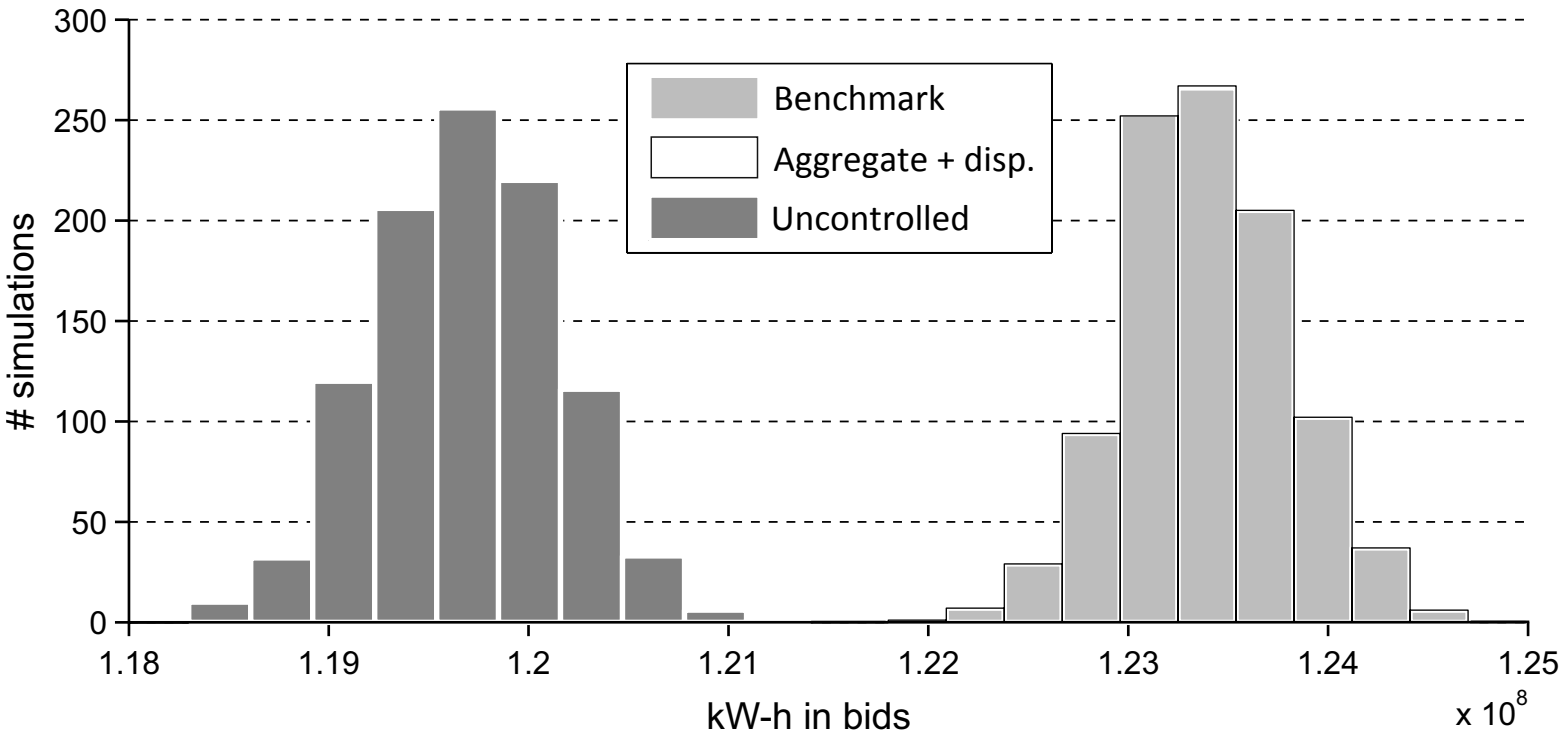
1. GIV at the University of Delaware
2. Challenge: large-scale scheduling
3. Solution: aggregate and dispatch
4. **Evaluation**
5. Validation

Evaluation

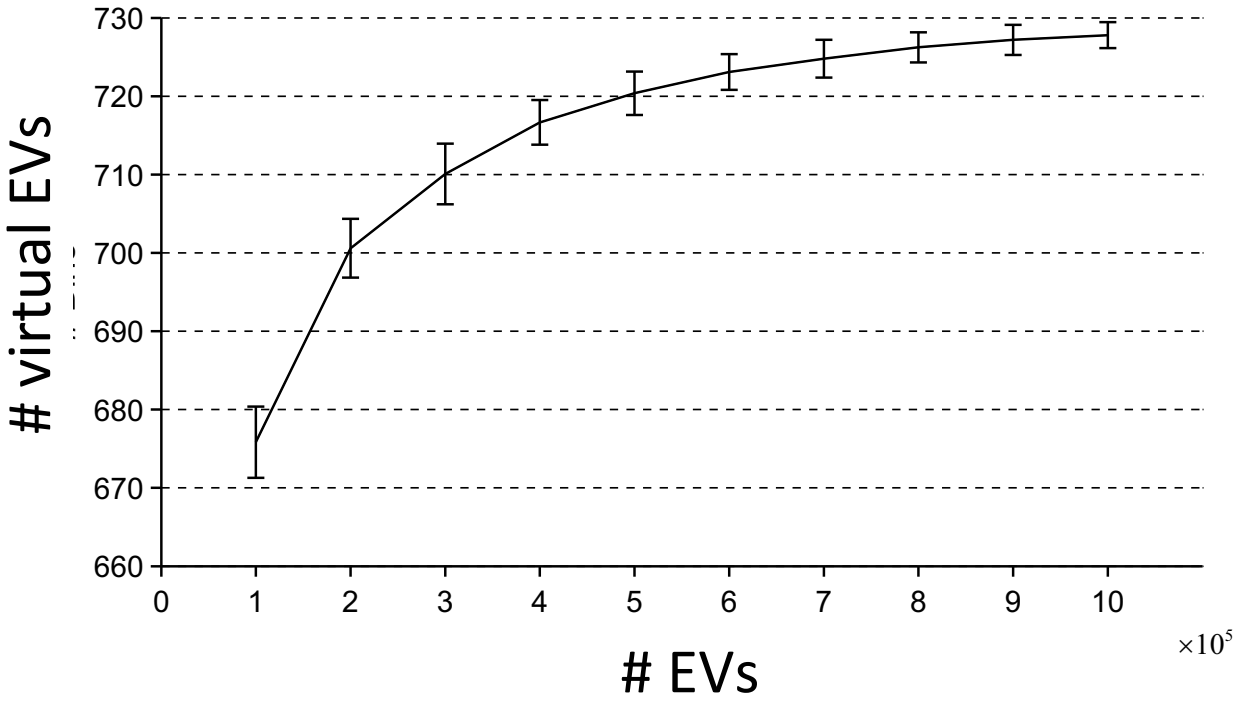




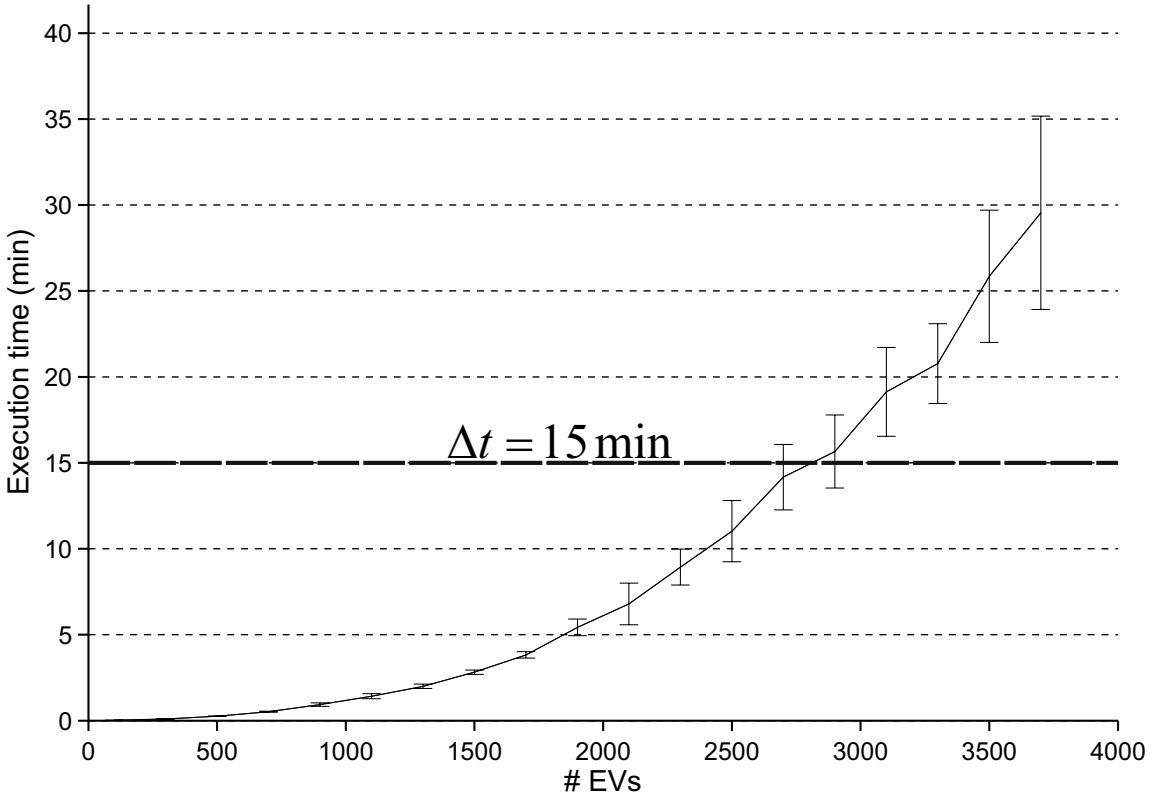
Bin-based GIV approach: key result



Aggregate and dispatch approach: key result



Bin-based GIV approach: key result



Overview

1. V2G scheduling at the University of Delaware
2. Problem: large-scale scheduling
3. Solution: aggregate and dispatch
4. Evaluation
5. Validation

Overview

1. V2G scheduling at the University of Delaware
2. Problem: large-scale scheduling
3. Solution: aggregate and dispatch
4. Evaluation

5. Validation

Demo

Conclusion

An aggregate and dispatch approach enables the provision of regulations services for a large amount of EVs.

Contact

stijn@udel.edu