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Self-adaptive Learning in Decentralized Combinatorial Optimization

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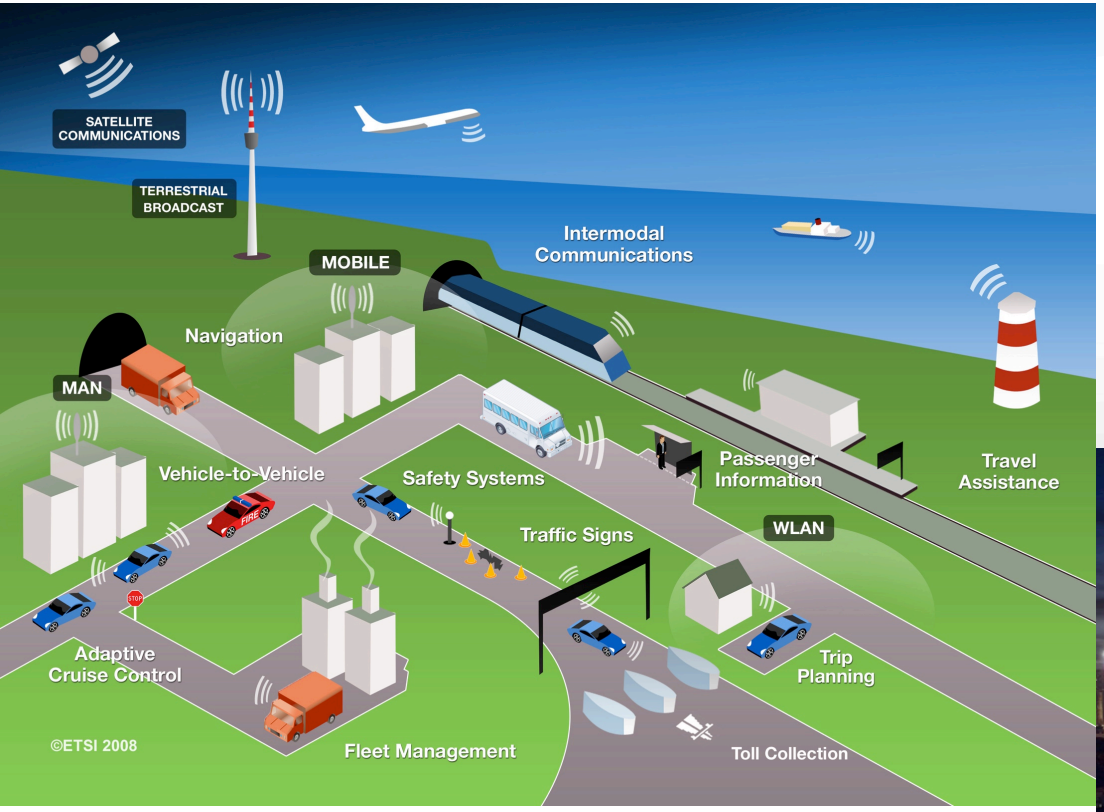
Collective Decision-making Problem

A new decentralized AI paradigm to follow up with the blockchain revolution

Smart Grids

Smart Cities



Collective Decision-making Problem

A new decentralized AI paradigm to follow up with the blockchain revolution

1. *Autonomous agents self-determine a number of plans to schedule/allocate resources*

2. *Agents have both a local & global objective: minimization of cost functions*

3. *Agents coordinate to select a plan that minimizes the cost functions*

Collective Decision-making Problem

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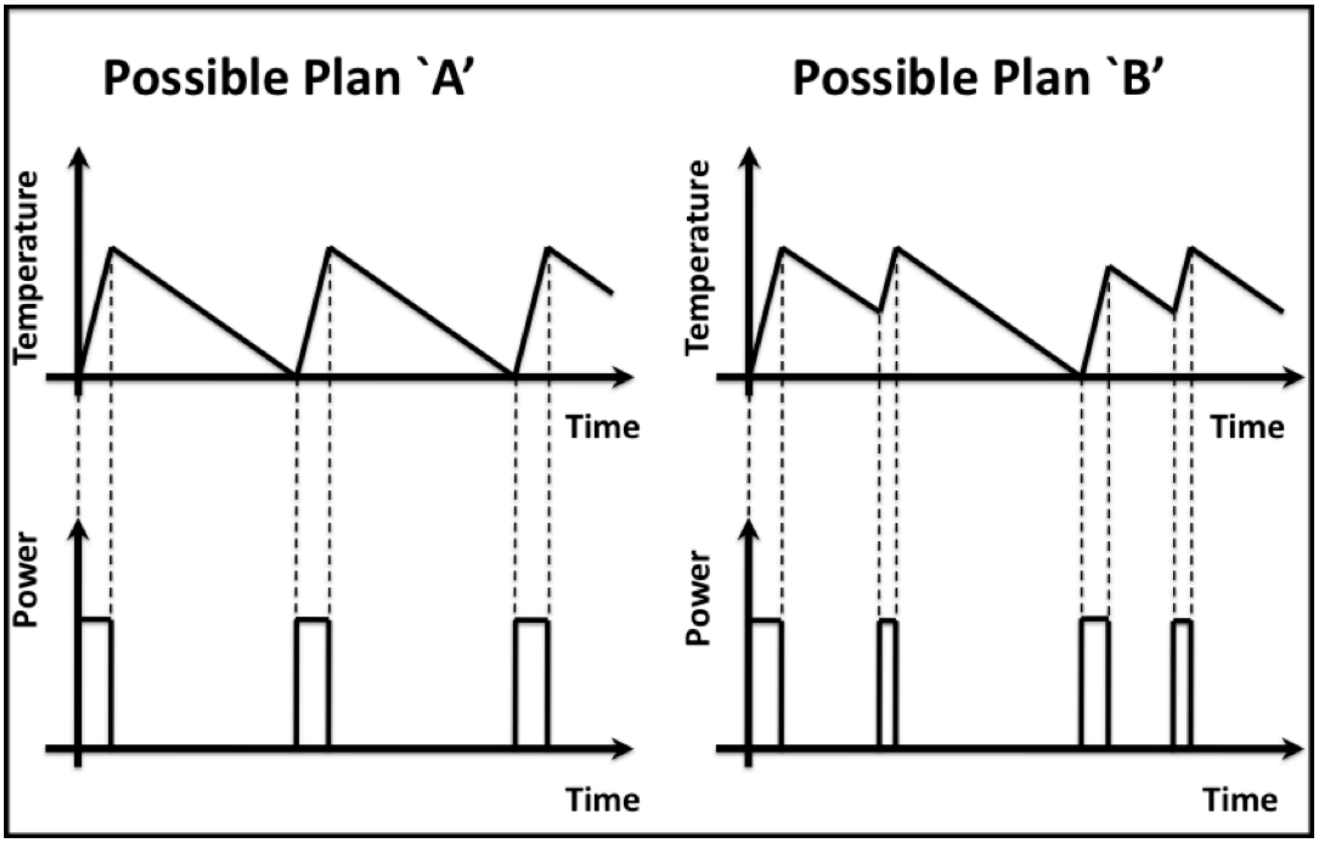
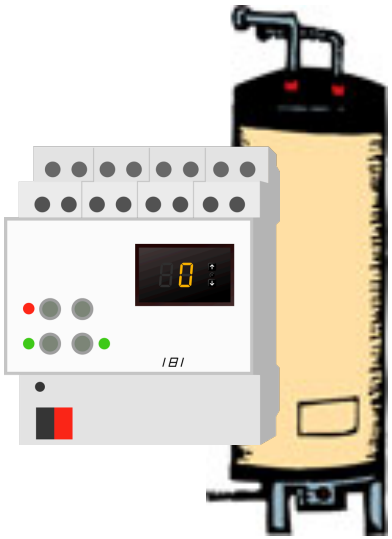
1. Autonomous agents self-determine a number of plans to schedule/allocate resources

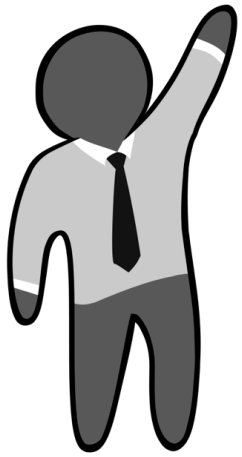
Planning Flexibility – Residential Power Demand





Water Heater

Planning Flexibility – Bike Sharing

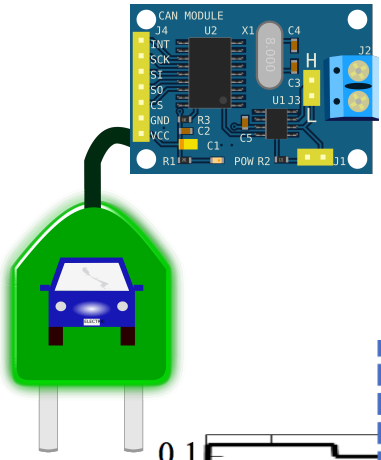


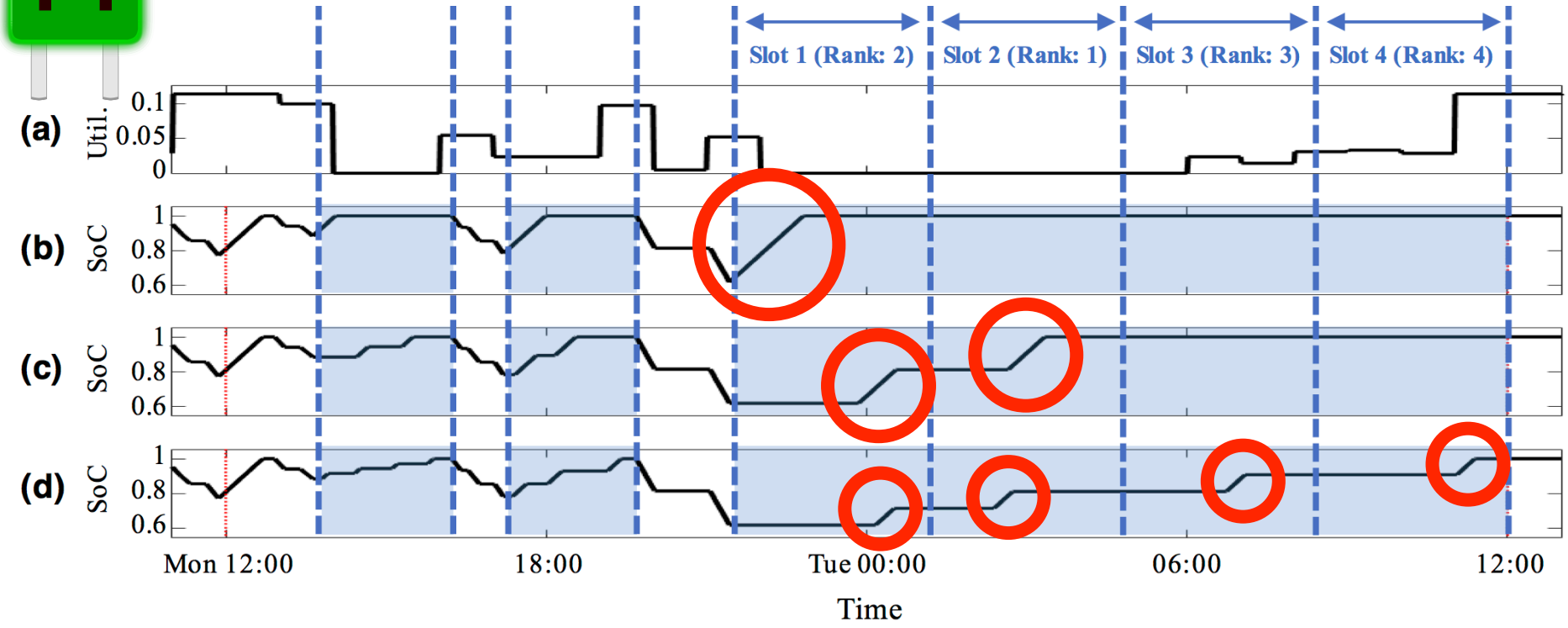
Location A

Location B

Location C

Planning Flexibility – Charging EVs





Collective Decision-making Problem

A new decentralized AI paradigm to follow up with the blockchain revolution

1. Autonomous agents self-determine a number of plans to schedule/allocate resources

Crowdsourced operational flexibility
autonomy, trust, privacy, no nudging

2. Agents have both a local & global objective: minimization of cost functions

Global System-wide Objectives

Can be locally optimized – *no coordination required*

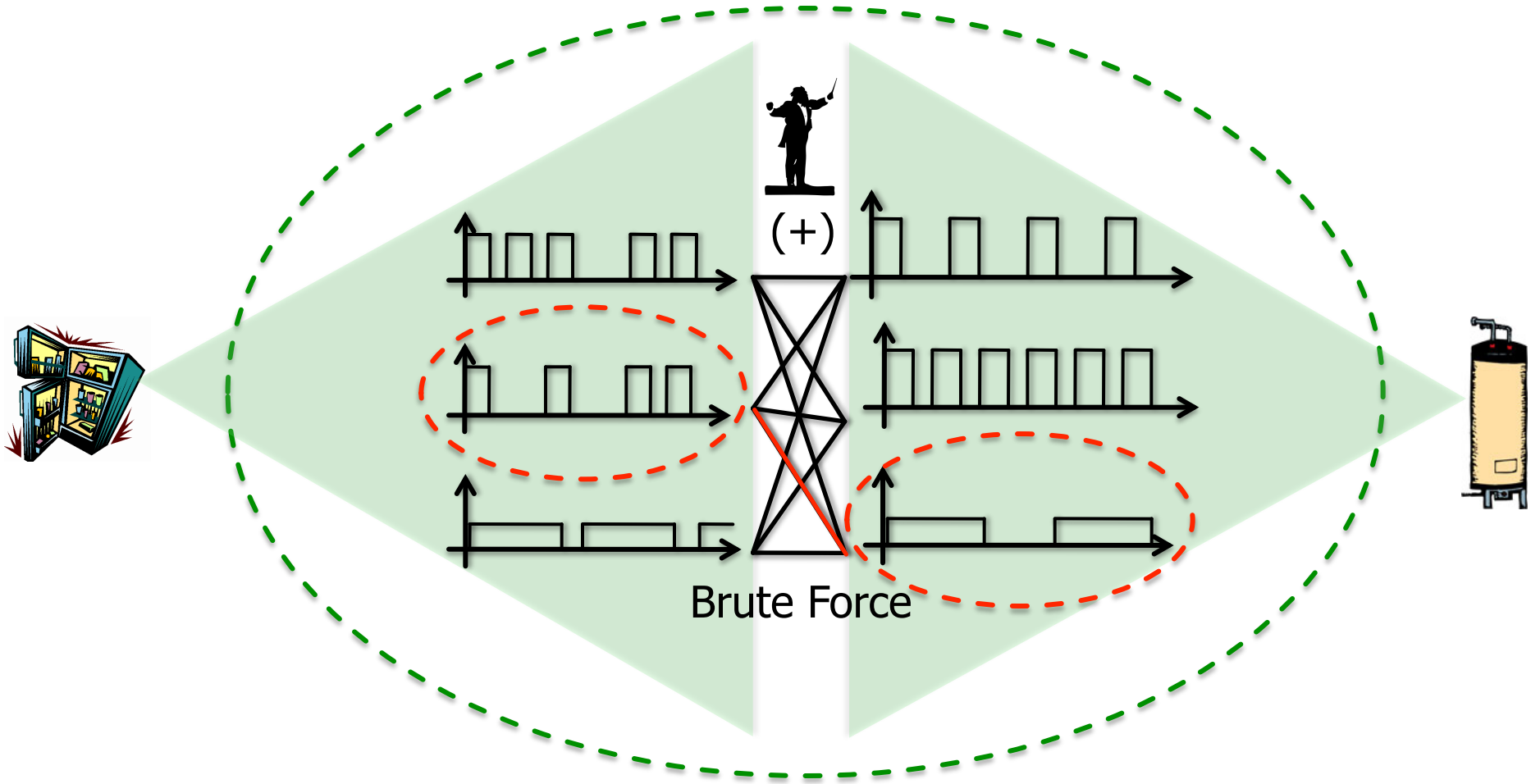
Linear vs. **quadratic** cost functions

Cannot be locally optimized – *require coordination & collective decision-making*

Example: **minimize variance** or **root mean square error**

generic stability & matching indicators

Centralized Computational Model



Complexity = # of possible plans$^{\#\text{ of devices}}$

Combinatorial optimization problem – NP hard

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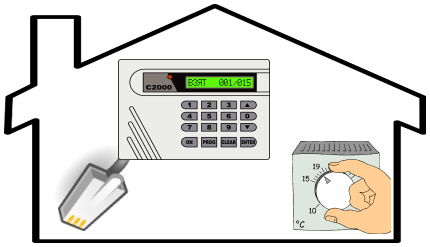
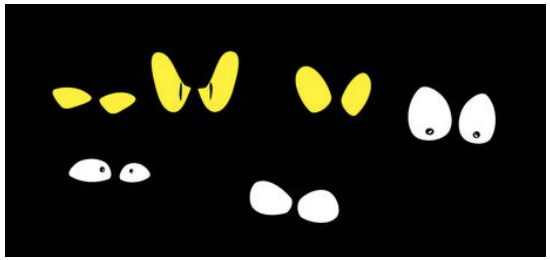
Socially responsible design
balancing individual & collective goals

3. Agents coordinate to select a plan that minimizes cost functions

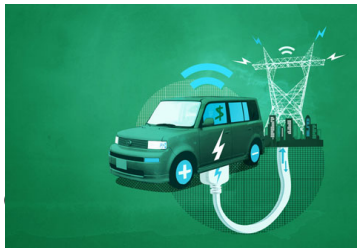
Smart Grids: Local-to-global Objectives



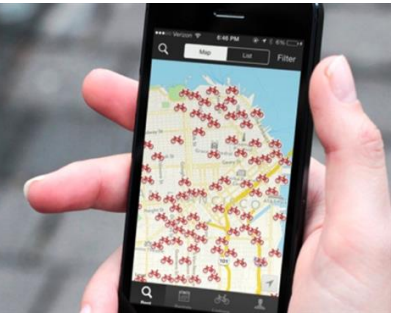
Local: make a shower, cook, laundry, charge EV



Global: prevent a blackout,
minimize production costs,
maximize use of renewables



Smart Cities: Local-to-global Objectives



Local: station to pick or leave a bicycle

Global: prevent overload/underload of bicycle stations
minimize manual bicycle relocations
minimize operational costs
minimize investment costs

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2. Agents have both a local & global objective: minimization of cost functions

Socially responsible design
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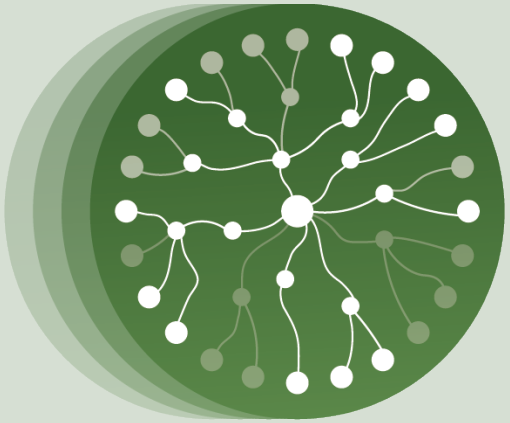
3. Agents coordinate to select a plan that minimizes cost functions

Crowdsourced computational resources
decentralized collective intelligence & self-management

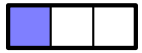
I-EPOS
Iterative
Economic
Planning &
Optimized
Selections



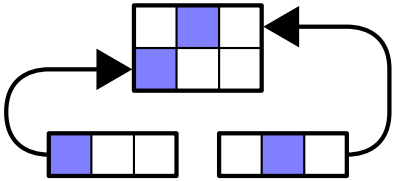
EPOS

epos-net.org

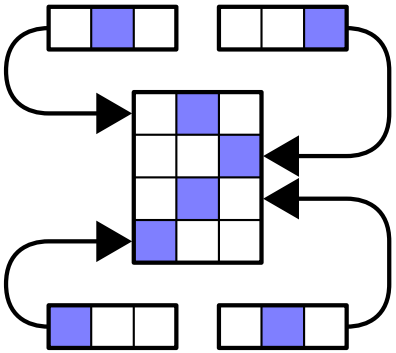
Plan Selection



(a) Selected plan.



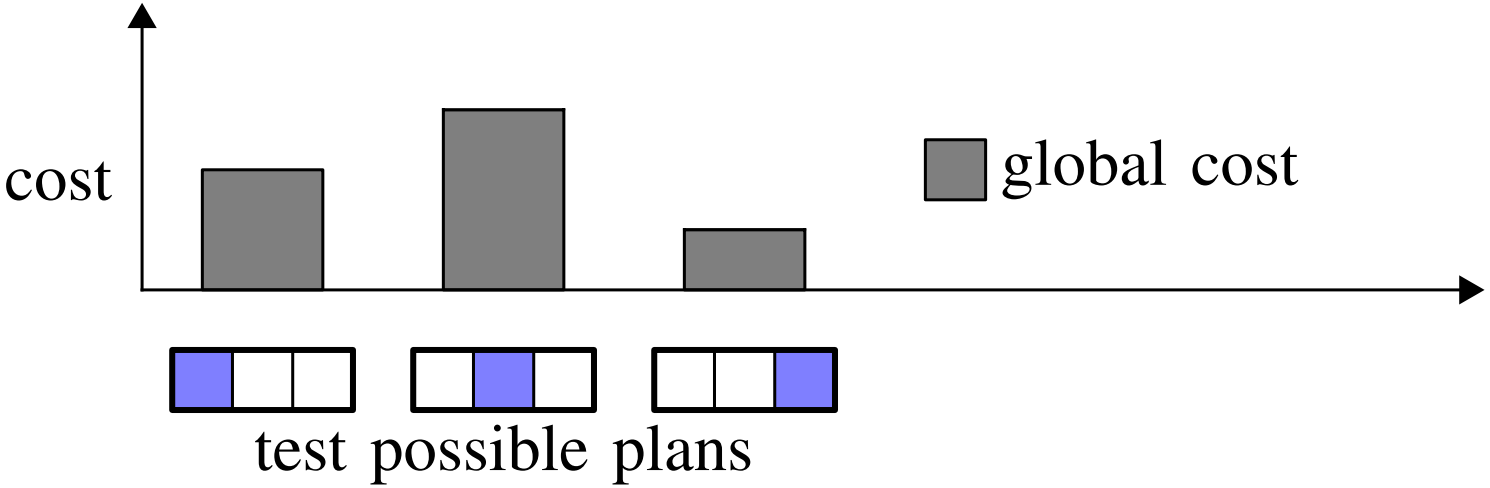
(b) Aggregated response.



(c) Global response.

λ=0 : *no agent preferences*

λ>0 : *bias towards agent preferences*

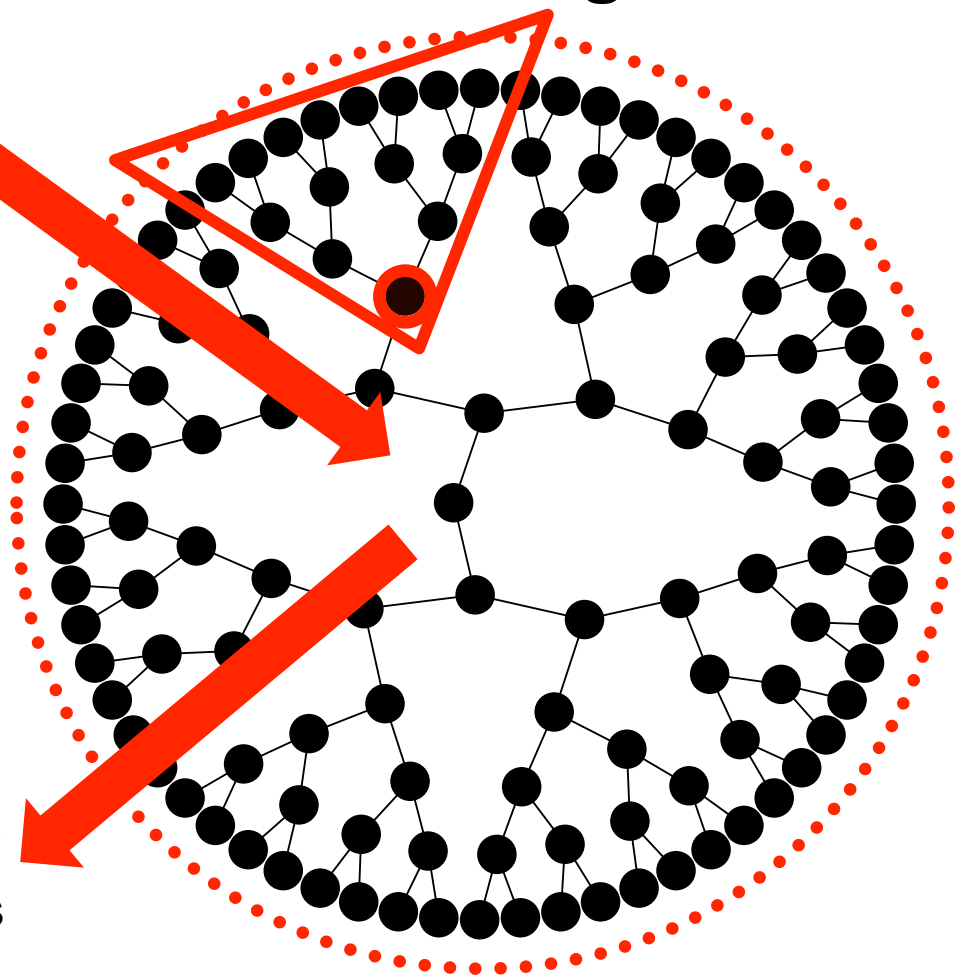


Decentalized Collective Decision-making

Bottom-up phase

Descendants aggregate choices

Adaptive & coordinated choices



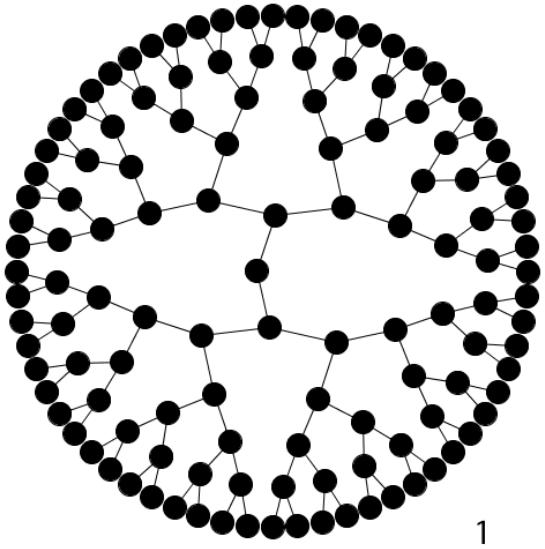
Top-down phase

Previous aggregate choices

1 bottom-up + 1 top-down phase = 1 learning iteration

Decentralized Learning

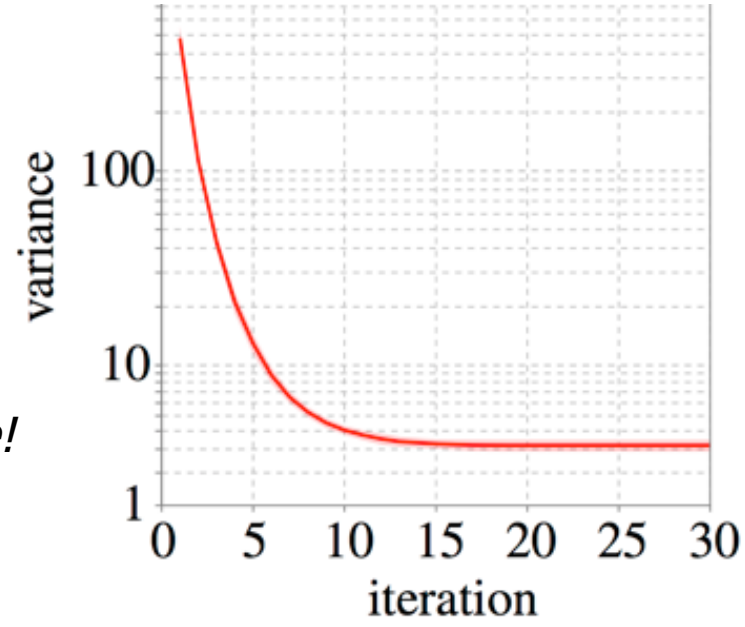
- 1000 agents in binary tree
- Objective: minimize variance
- 16 possible plans
  (size 100, standard normal distribution)
- λ=0, *no preferences*



Striking findings

Monotonously improving/learning solutions!

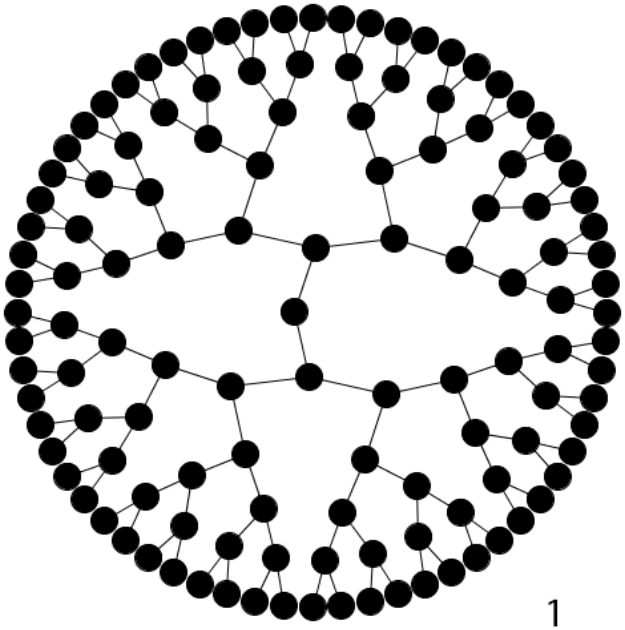
Global optimality: Top 3% of the solution space!



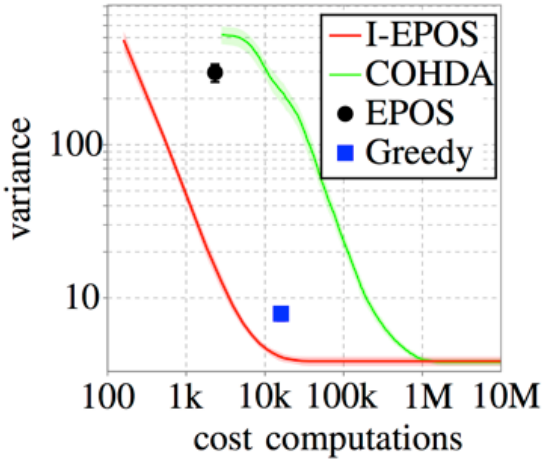
State of the Art Comparisons

Cost-effectiveness: I-EPOS vs. COHDA

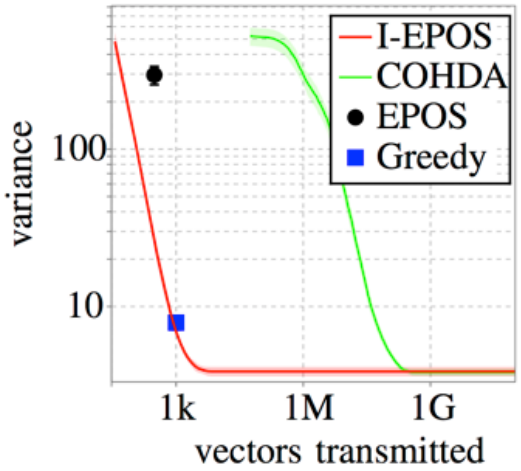
Converges faster with fewer changes!

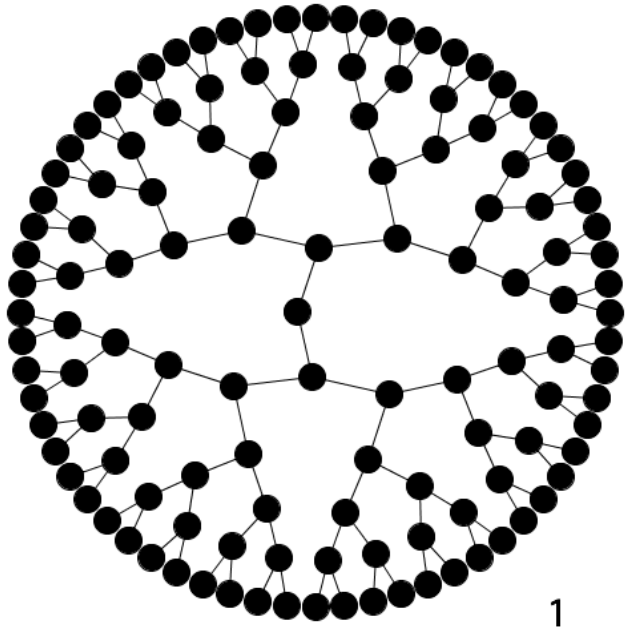


I-EPOS



vs.

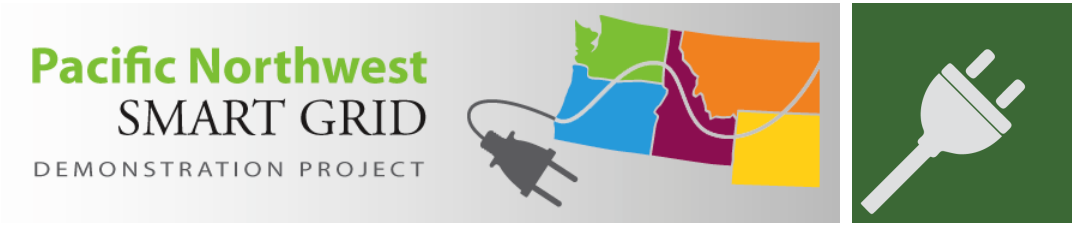




COHDA

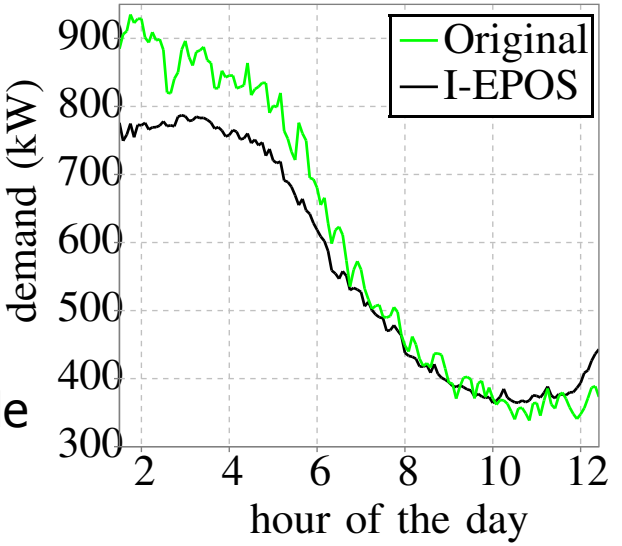
Self-managed Sharing Economies

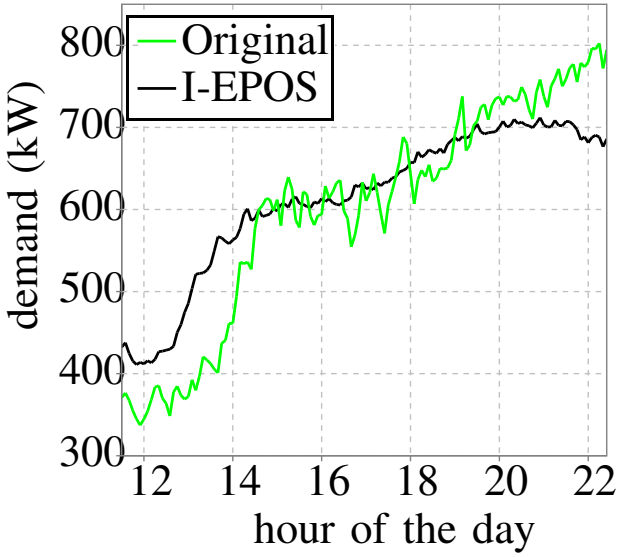
Smart Grids – Residential Power Demand



1000 households, 13 plans, generated by load-shifting

Agent preferences (λ): How much load-shifting is tolerable





Smart Grids – Charging EVs

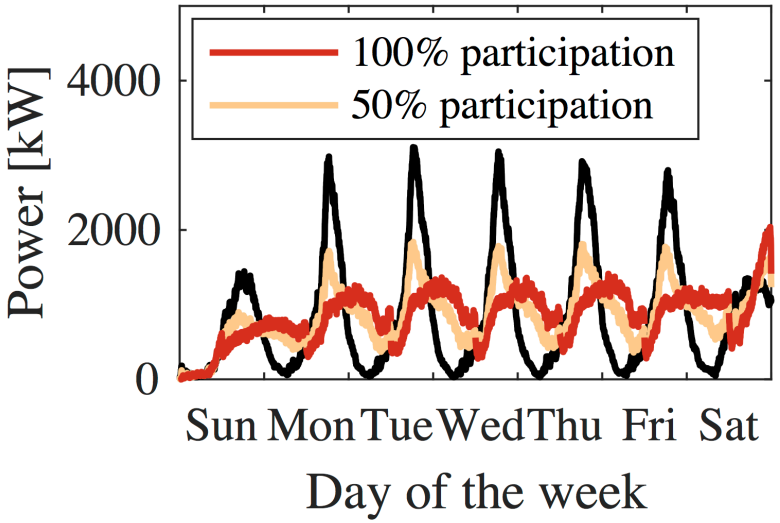
2910 electrical vehicles

4 plans, generated using historic trips

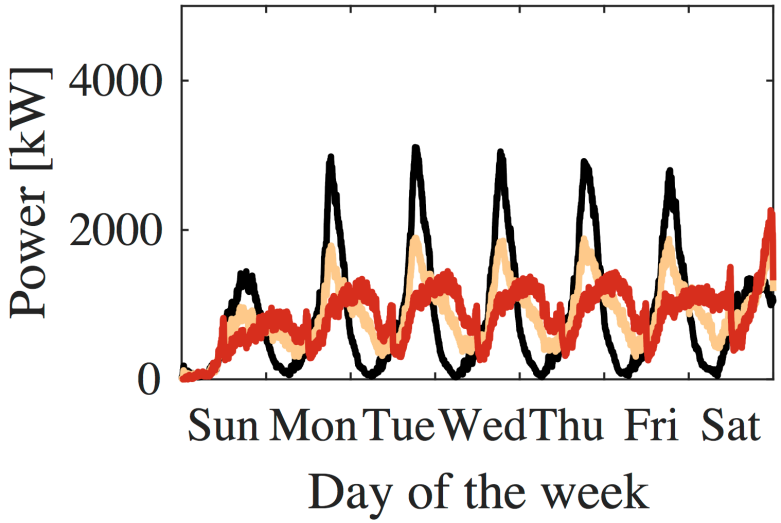
100% & 50% vehicle participation

Daily vs. weekly planning & optimization

Daily planning & optimization



Weekly planning & optimization



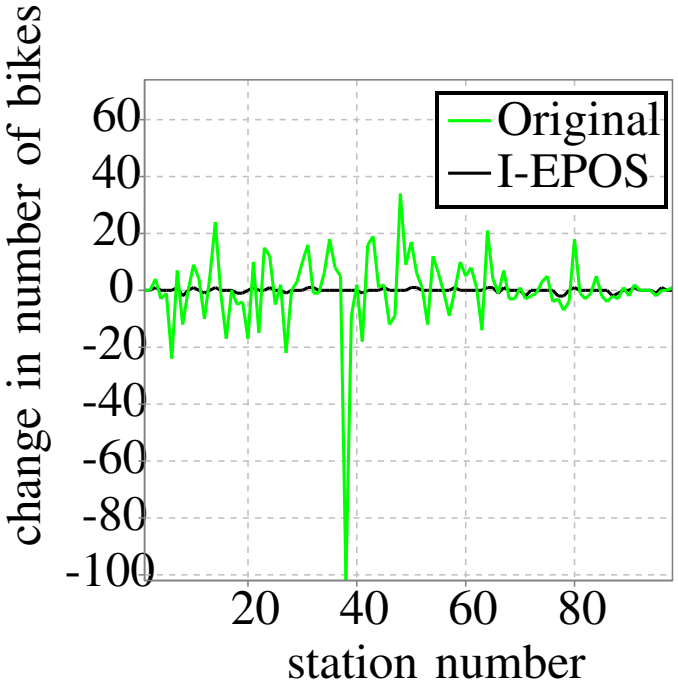
30%-80% reduction in variance

Smart Cities – Bike Sharing

Hubway Data Visualization Challenge

1000 bike users, varying # of plans, generated using historic trips (time: 08:00-10:00)

Agent preferences (λ): Average likelihood of a trip in the historic data



Conclusions

Grand challenge
decentralized learning in combinatorial optimization made feasible

I-EPOS: **Striking performance** against state of the art

One generic decentralized algorithm
applied in several self-management scenarios
of participatory sharing economies

Future Work

Linking the organizational aspects, e.g. social networking, with the learning capacity

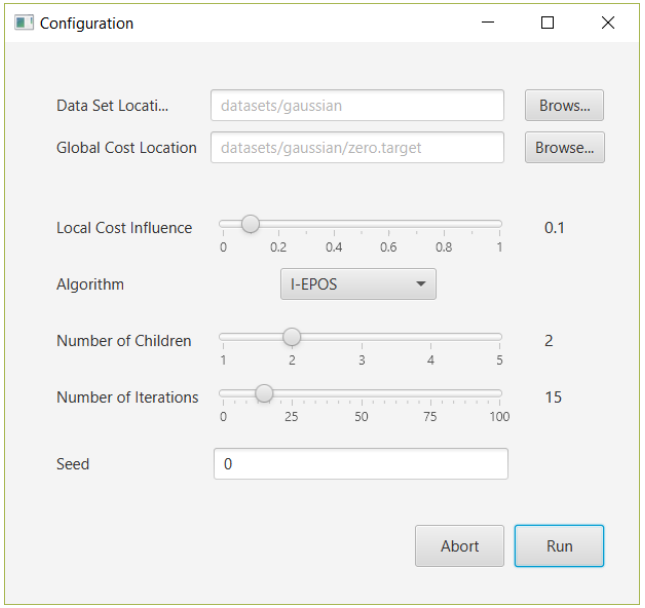
Incentivization scheme based on **blockchain technology**

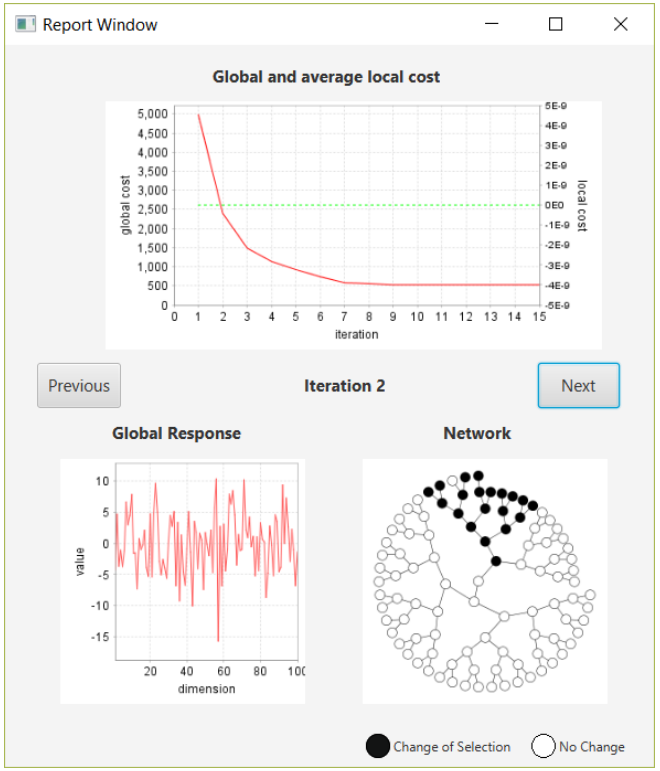
Other applications

1. Load-balancing of cloud and data center infrastructures
2. Sustainable consumption (ASSET EU project)
3. Vehicle sharing for traffic optimization

Website: epos-net.org

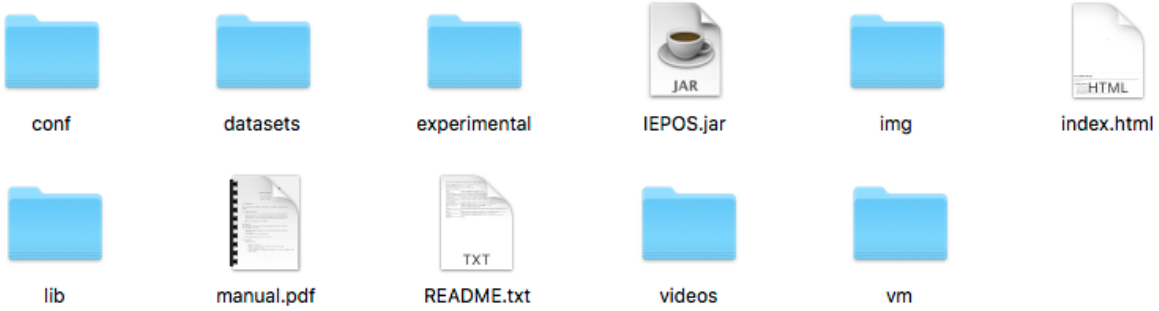
Community Software Artifact





Download the software exemplar (2.7 GB)
http://epos-net.org/shared/I-EPOS.zip

Follow the instructions
index.html



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Questions?

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